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Construction and maintenance of artisanal fishing harbours and village landings

Food and Agriculture Organization of the United Nations

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EDITORIAL NOTE

Construction and maintenance of harbours and landing places for fishing vessels; this manual is the latest in the training series of the Fishing Technology Service of FAO. It was conceived as a result of the increasing demand in many developing countries for safer, better and cleaner facilities for fishing vessels, particularly the smaller craft used by small-scale and artisanal fishermen and women.

During the preparation of the manual, FAO undertook the elaboration of an International Code of Conduct for Responsible Fishing that would include, *inter alia*, certain principles and guidelines concerning harbours and landing places for fishing vessels. Specific reference is made to the need for the competent authorities to adopt standards and follow guidelines for the design, construction and maintenance of harbours and landing places for fishing vessels in order to ensure:

- safe havens for fishing vessels;
- that fresh water supplies are available;
- the provision of adequate sanitation arrangements;
- that waste disposal systems (including oil and oily water) are provided;
- that there would be no pollution from external sources (non-fisheries activities);
- that there would not be any pollution arising from fisheries activities;
- the provision of adequate servicing facilities for vessels, vendors and buyers;
- that maintenance programmes include the monitoring of the effects on the environment of operations conducted at the facility;
- compliance with relevant conventions concerning pollution of the aquatic environment; and, where appropriate
- integration with other users as in the case of non-exclusive facilities for the fishing industry.

This manual will be used as reference material for the Annex to the Guidelines for Responsible Fishing Operations.

PREFACE

Many fishing harbours started off as artisanal fishing boat shelters. When building an artisanal boat shelter, proper use of the existing natural features (such as sheltered areas, open beaches or river mouths) will make it easier and cheaper to upgrade the shelter to a proper fishing harbour when needed.

This booklet has been written for small fishing communities to help them understand how to make the best use of their resources in building a good and serviceable shelter, without forgetting that one day the shelter may be upgraded to a fishing harbour.

To apply some of the suggestions in this booklet, a basic knowledge of mathematics is required and the reader may have to obtain help from the local school-teacher or extension worker. In Chapter 9 you will find the drawing conventions, dimensions and weights used in this booklet.

The equipment required to carry out the work described in this booklet falls into two categories:

- Expensive equipment that should be borrowed or leased from a central government store or contractor with an operator.
- Relatively cheap equipment that can be bought by the community and used by locally appointed people.

The booklet may also be useful for schools where fishing is taught and for training village harbour-masters.

FAO would very much like to know what readers think of this booklet, the language, style and pictures. Readers' comments, criticism and opinions will help us to make future books better. So please write to the Fishing Technology Service, Fishery Industries Division, Food and Agriculture Organization of the United Nations, Viale delle Terme di Caracalla, 00100 Rome, Italy.

CONTENTS

1. FINDING AN IDEAL SITE

An ideal site should basically offer the following:

- Total or partial protection from prevailing sea storms.
- Water depth in the range of 1.5 – 3 m within easy access from the shoreline.
- Good access from the land-side for either pedestrian or car traffic.

Preferably, the site should also offer the following:

- A small tide-level variation.
- Good beaching facilities in the vicinity (sandy beach).
- Absence of seaweed.

However, an ideal site, such as a protected sandy inlet, does not always coincide with the wishes of the local fishermen. Often the ideal site for a shelter does not lie within a reasonable walking distance from the village. In such cases, the best use has to be made of the environmental conditions closer to home.

When examining a site, the first three conditions usually decide the eventual cost of the shelter. If the site is not protected against prevailing storms, more money will have to go into protecting the shelter by building a bigger and stronger breakwater. On the other hand, if the site is well-protected, a smaller, cheaper finger-jetty landing may be more suitable. If the water is too deep, all the structures will have to be bigger and hence more costly. If the area is too shallow, on the other hand, routine dredging will be needed to keep the shelter open for passage.

Needless to say, the area must also be accessible from the shore-side. Sometimes a footpath may suffice, but more usually some sort of road access is necessary for light trucks in both wet and dry seasons.

No two locations are identical. The following are simplified examples that should be used only as a guide to selecting an appropriate site for a landing-quay or -jetty.

OPEN BEACH

A long open beach (at least 1 km long) facing the ocean (Figure 1) is typical of many fishing communities. Here the only suitable landing is a beach landing or, if the waves are not too large, a simple jetty on piles placed anywhere along the beach close to the village.

The most important thing to observe is the area where incoming waves break. The jetty should reach beyond this area so that waves do not break against it and damage the boats tied up to it. If the waves are big, say over 2 m high, the jetty has to be very strong to resist the wave action. No attempt should be made to build anything solid (such as a breakwater) on a sandy beach. This would interfere with the free movement of sand and may even lead to the beach disappearing over a few years. If a breakwater is considered necessary, then expert advice should be sought prior to construction.

SANDY BAYS

Figure 2 shows a small sandy bay flanked by two headlands. These heads of rock provide a good foundation on which to build a small quay without the risk of damage to the beach. A rock outcrop also provides shelter against the prevailing wave direction. Two quays, one on either side of the outcrop, would provide an all-weather facility, with either the north side or the south side in use, depending on the prevailing wave conditions. Any solid structure sticking out on to the sandy beach should be avoided.

Figure 1
Open beach landing-jetty

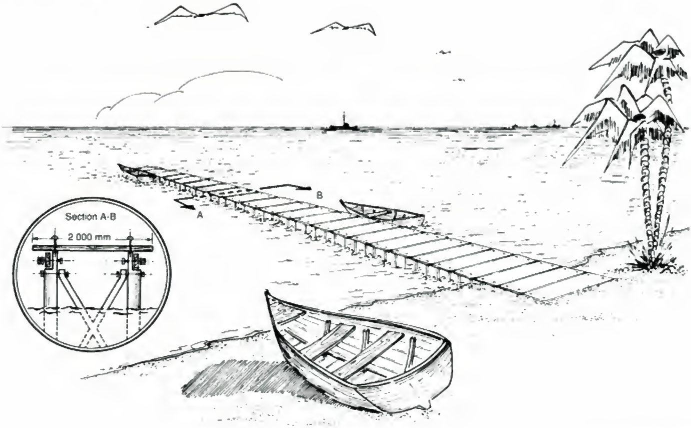
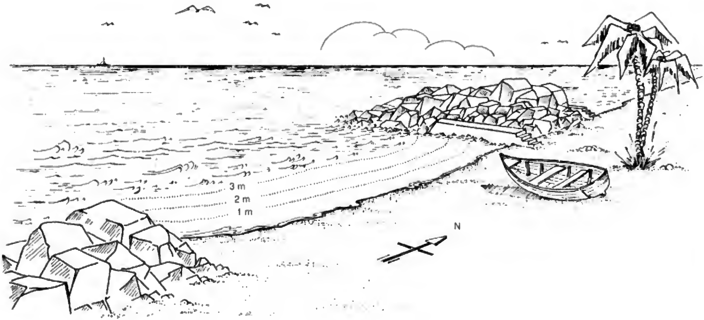


Figure 2
Making the best use of a natural rock outcrop



REEFS

Offshore reefs are a very common feature along some coastlines and on coral islands. As a general rule, a stone breakwater should not be built on the reef where big incoming waves may wash it away (Figures 3a and 3b). As well as demolishing the breakwater, the waves would also dump the stones over a wide area, thereby turning them into a hazard to navigation.

A stone breakwater should be built inshore of the reef (Figure 3d) where the reef itself protects the breakwater. If the area inshore of the reef does not allow a safety margin of about 30 – 50 m, a concrete wall anchored to the reef could be considered (Figure 3c). If the reef consists of living coral, however, every attempt should be made to preserve it in its natural state and to find an alternative site elsewhere along the coastline. Living coral is a primary source of the sand that makes up the coastline. A dead coral-reef is of little use as protection because wave action will eventually break it all down into sand, exposing the whole coastline to wave attack. Live coral, on the other hand, constantly rebuilds itself.

RIVERBANKS

Figure 4 shows the proper site for a landing on a meandering (curving) river. Rivers in general carry tonnes of silt and sand in suspension, especially during floods. This silt and sand is then deposited in places where the water-flow is slower than normal. When a river flows around a bend, the water on the inside of the bend flows far more slowly than the water on the outside. This causes the silt and sand to fall out of suspension and deposit themselves on the inner reaches of the bend in the river. On the opposite side, however, the higher speed of the water-flow constantly erodes the bank while preventing the silt from being deposited. Although the stronger current at the outer bank makes it more difficult to navigate, a landing built here may be cheaper to maintain because it will need less dredging than one built on the inner bank. Lower maintenance costs may mean the difference between a serviceable landing that is open all the year round, and one that has to close because the costs of dredging are too high.

RIVER MOUTHS

River mouths usually offer good protection against bad weather. However, river mouths also tend to shift position, especially in low-lying areas where there are monsoons. In such cases, special care should be taken when deciding on the type of structure and its position in relation to the coastline.

Along the coastline any kind of vegetation (especially mangroves) should be preserved because vegetation is the only natural means of controlling the shape of the coastline.

Figure 3
Use of natural reefs

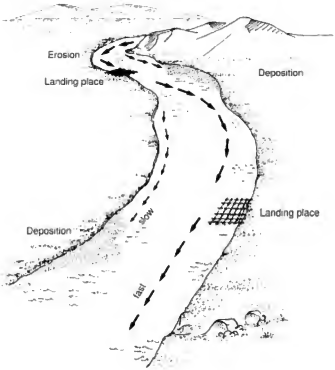
Figure 3a

Figure 3b

Figure 3c

Figure 3d

Figure 4
Optimum sites for a landing place on a meandering river



2. MAKING A SITE SURVEY

A site survey is a way of "freezing" the landscape into the form of a map, much as a camera does when it takes a photograph. Unlike a photograph, however, the survey provides many more data than would be seen by the naked eye.

WHY IS A SITE SURVEY NECESSARY?

In the past many artisanal shelters were built at convenient locations without much attention being paid to environmental factors such as wave heights, uncharted reefs, currents, seaweeds and sand drift.

Problems arose from these factors and many of the problems that used to be considered minor have now developed into major ones. Some shelters, for example, foul up with seaweed because the shelter mouth is facing in the wrong direction. Other shelters silt up because they have been placed directly on a beach, or they become inaccessible in rough weather because there are reefs too close to the entrance channel.

A good site survey is therefore essential to make sure that the shelter or landing is easy to use and free of maintenance problems under normal conditions.

WHAT DOES THE SITE SURVEY CONSIST OF?

A good site survey should produce the following items:

- *Topographic map*. This is a map showing all the relevant *land* details near the proposed shelter. Features such as the village, pathways, roads, wells, the electricity supply cables, beaches, rocky outcrops and vegetation appear on a topographic map.
- *Contour map*. This shows the *sea-bottom* depths in and around the proposed shelter. Depths are shown either in grid form or as contours.
- *Tide survey*. This is a table showing the maximum and minimum tide-levels at the proposed location.
- *Tidal stream survey*. This is a map showing the location, direction and strength of tidal streams.
- *Wave height survey*. This is a table showing the direction, frequency and intensity or heights of waves for the area proposed.

WHAT KIND OF INSTRUMENTS ARE REQUIRED FOR A SURVEY?

Several kinds of instruments are required for a proper survey. These instruments have been divided into two groups, Group A and Group B.

The prices of all the items in groups A and B vary considerably depending on the country of origin, the brand name of the manufacturer and other factors.

The instruments in Group A are very expensive and should be hired or borrowed from the local public works office or contractor, preferably with the services of an operator or surveyor from the same office. Instruments from Group A are shown in Figure 5 to Figure 9.

Figure 5
Theodolite

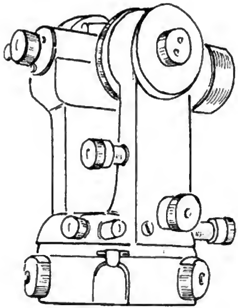
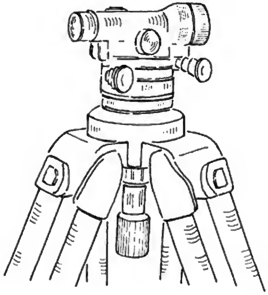


Figure 6
Level



• The *theodolite* (Figure 5) is the basic instrument for setting out lines and angles over wide distances. The original theodolite was a purely optical instrument, but nowadays most theodolites come with an electronic distance-measuring attachment. For the purposes in this booklet, the purely optical instrument will suffice.

• The *level* (Figure 6) is the surveyor's second-most important instrument. It is used to measure the difference in level of two points placed far apart.

Figure 7
Tripod

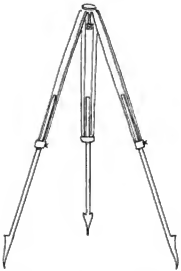
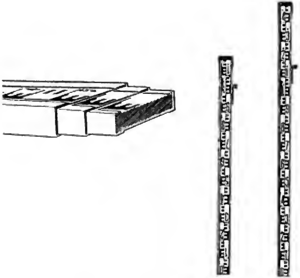


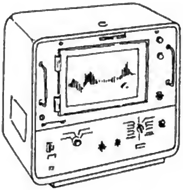
Figure 8
Staff



- The *tripod* (Figure 7) is used solely for setting up the theodolite or the level. One tripod is usually used for both items.
  When borrowing a theodolite or level from an office, make sure that the tripod anchor bolt fits both instruments as some brands are not interchangeable, i.e. the tripod may fit the theodolite but not the level. In this case a separate tripod is required for each instrument.

- The *staff* (Figure 8) is used only with the level. If the level is new, the accompanying staff will be numbered the right way up; if the level is old (20 years and over) the staff may be numbered upside down. New staffs are made of metal and old ones of timber. Check the graduations on the staff; they should be in metres.

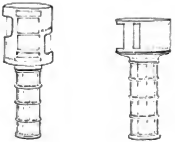
Figure 9
Echosounder



- The *echosounder* used for surveying (Figure 9) is not the type of echosounder used on fishing boats to locate fish. The surveyor's echosounder is a precision instrument and is used solely for the accurate measurement of the water depth.
  The hydrographic office, the public works department or the port authorities usually own this type of echosounder which they use to monitor the silting up of approach channels to major ports. A portable instrument of this kind should come with a pair of special battery cables, a separate transducer head, one or two rolls of thermal paper and a spare stylus. A fully charged 12-volt car battery is required to operate it.

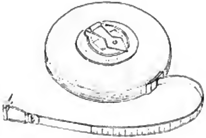
The items in Group B are relatively cheap and some may even be assembled on-site from inexpensive materials. Some of the instruments from Group B are shown in Figure 10 to Figure 16.

Figure 10
Optical square



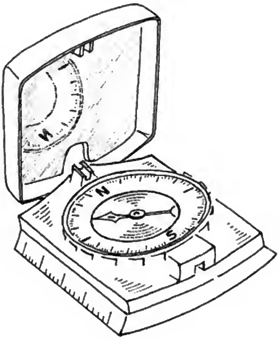
- The *optical square* (Figure 10) is used for giving right-angle offsets to a straight line drawn on the ground.

Figure 11
Tape-measure



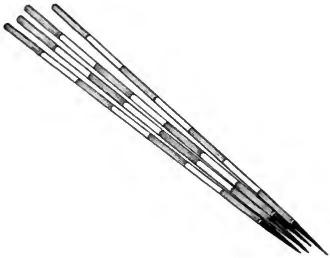
- Fibre or plastic *tape-measures* (Figure 11) typically come in lengths of 20, 30, 50 or 100 m. Prices of tape-measures vary considerably. A steel tape is more precise, but requires more maintenance and is much more expensive. For normal setting-out work a plastic tape is sufficient.

Figure 12
Compass



- A small hand-held oil-encased *compass* (Figure 12) is required for taking bearings or headings from a permanent structure (for example, a hill or the tip of an island) when observing natural phenomena, such as wind, waves and currents.

Figure 13
Ranging rods



- *Ranging rods* (Figure 13) are coloured poles that are used in tracing out lines on the ground.
Ranging rods can either be purchased outright or made from pieces of straight pipe, roughly 1.5 m long, with red and white bands (150 mm wide) painted as shown in Figure 13.

Figure 14
Float-line

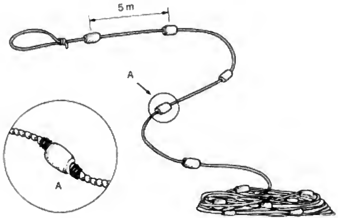
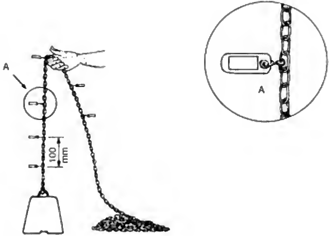


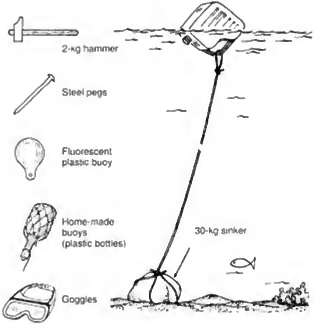
Figure 15
Sounding chain



• A *float-line* (Figure 14) consists of a polypropylene rope, 6 mm in diameter, with small red-coloured cork floats at 5-m intervals and other-coloured floats at 10- 20- or 50-m intervals. A float-line is used to measure the distance at sea from a fixed point on the shoreline. Ideally, the float-line should be about 200 m long and should be stored either on a revolving drum or in a round fishing basket.

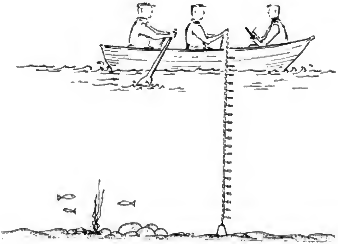
• A *sounding chain*, or leadline (Figure 15) is a normal light chain with a 1-kg weight attached to the end. The chain should be graduated at 100-mm intervals. It is used to measure the depth of water.
A sounding chain is very easy to assemble from normal metal chain, plastic tags and wire. The weight should, ideally, be made of lead.

Figure 16
Other items



- Other items that can be bought or made are shown in Figure 16. The pegs are needed for laying important marks on the ground. Red or white paint may also be needed to paint marks in places where the pegs cannot be used, such as on a stone wall or on a tree. Floats and sinkers are required for marking points out at sea.

Figure 17
Survey boat



- A *boat* is required for taking depth readings out in the open sea. The survey boat (Figure 17) should be made of timber and be slightly heavy to counteract light cross-winds. Fibreglass boats tend to be carried off-course very easily.
When using a hand-held chain, a pair of oars are necessary. Three people are needed on the survey boat: the pilot, the person who holds the chain and an assistant who records the readings on paper.

GETTING STARTED

This booklet assumes that when a theodolite, a level or an echosounder have been borrowed or hired from an office, someone from that office has been made available to operate the instrument.

Topographic map

The topographic map has to be made by a trained surveyor. Details of how a topographic map survey is carried out are too complicated for this booklet to discuss.

Contour map

A contour map is a plan of the depth of the sea-bed. Each contour of equal depth is indicated by a line on which the depth, in metres, is clearly marked.

The survey carried out to obtain the contour map is called the *hydrographic survey*.

In a hydrographic survey, the actual measurement of the depth is the easy part. The main problem is knowing how far the boat is from the coastline when the depth is recorded.

Figure 18
Using a float-line to fix the position of each sounding (boat B)

For example, boat A in Figure 18 has no point of reference in relation to the coast. Boat B on the other hand, is using a calibrated float-line (see Figure 14) to obtain a *fix* or position with respect to the coastline. In this case the coastline is 20 m away on the straight line between the peg and the buoy.

The float-line should be set up or floated out between a peg on the coastline and a floating buoy offshore, as shown in Figure 18. The peg driven into the ground is simple to set out and should fit into the topographic map of the shore around the proposed shelter.

There are two simple methods for setting out the position of the buoy to which the float-line is to be attached:

- The *ray method* (Figure 19) is considered the simplest and is ideally suited to confined work, such as when working off a solitary offshore rock or a headland. The instruments required are a theodolite and about 20 buoys.

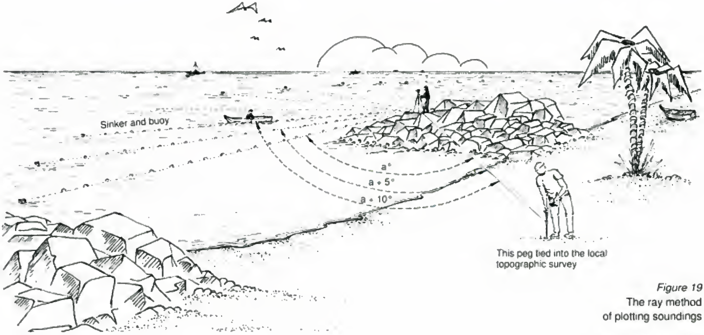


Figure 19
The ray method of plotting soundings

This method involves setting up the theodolite on a vantage point that can easily be tied into the topographic survey. At equal angular intervals, say at every 5 or 10 degrees, a buoy should be dropped in place roughly 200 m from the theodolite. These angles should be measured from a fixed mark or benchmark, such as an electricity pole, a big tree or the corner of a building. This will produce a fan shape when the buoys have been dropped in. Float-lines should then be anchored from the peg under the theodolite to each of the buoys around the fan. By taking into account the position of the peg on the ground and the angle of each buoy from the benchmark, the depth readings can be plotted on paper in the right place in the form of a fan.

- The *parallel line method* (Figure 20) is much more accurate, but requires considerably more groundwork.

  The equipment needed is: an optical square; two ranging rods; about 10 pegs and buoys; and a 100-m measuring tape.

  First, set out a straight baseline along the beach with a ranging rod placed at either end. The baseline should be at least 100 m long. If the coastline is rocky, a steel peg should be driven into the ground every 5 m along the baseline. On flat beach, however, one steel peg every 10 m is enough. Then, with the help of the optical square, a buoy should be dropped offshore at right-angles to each peg. A float-line should be anchored between each peg and its corresponding buoy offshore. By tying the baseline into the topographic survey, the depth readings can be plotted on paper in the right place.

It is always good practice to extend the survey for 50 – 100 m on either side of the proposed shelter or landing.

The actual depth of the water may be read by simply lowering the sounding chain (Figure 15) every 5 or 10 m along the float-lines. The person using the chain calls out the readings to another person in the boat who records the figures on paper in the correct order. This type of recording yields a grid with spot depths only, as shown in Figure 21.

If a hydrographic echosounder and an experienced operator are available, the soundings are recorded on a special paper roll by the instrument itself. In this case, only the echosounder operator need accompany the boat pilot on the survey vessel up and down the graduated float-lines. A continuous bottom profile is obtained on a continuous strip-chart.

This strip-chart can be read to the nearest 5 mm.

When making a contour map or grid map remember:

- The sounding chain must reach the bottom in a straight vertical line. When a sounding chain is being used, the vessel must be still while the reading takes place. If the area is subject to strong tidal streams, the weight of the sinker should be increased by attaching weights to the chain.
- If a hydrographic echosounder is being used, readings should be taken as the boat approaches the shore on an inbound run (Figure 20). If the vessel's skipper starts an inbound run, say 50 m from the float, it will be easier to position the boat parallel to the float-line.
- Surveys should not be carried out on stormy or windy days. Flood and ebb periods in strong tidal areas should also be avoided. The sea should be perfectly calm.
- In rocky areas, before the float-lines are removed, a swimmer wearing a pair of goggles can swim up and down the surveyed line looking for submerged rock outcrops or wrecks. The swimmer can then point these out by placing small floats near them. The depth of water over each

Figure 20
The parallel line method of plotting soundings

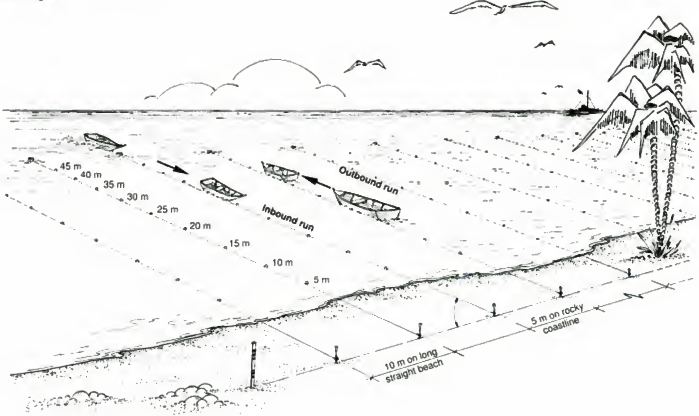
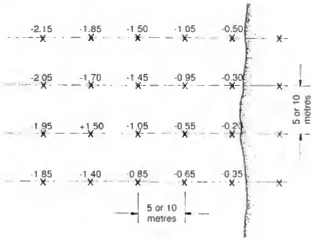


Figure 21
Soundings plotted using the parallel line method (the "+" sign indicates a rocky outcrop sticking out above mean sea level or msl, depths are in metres)



obstacle can then be measured and the small floats plotted on the survey map by taking a series of fixes from the baseline with the theodolite.

A detailed grid map (Figure 21) is usually sufficient for normal day-to-day coastal work. At local village level no attempt should be made to convert a grid map into a contour map; this should be left to a professional surveyor at the public works office. If a hydrographic echosounder was used for the survey, the same operator is the best person to interpret the strip-chart and produce the contour map.

Tide survey

You may need the help of an experienced surveyor or extension worker to help you fully understand the following series of surveys.

It is most important that tides should not be confused with tidal streams. A tide is a periodic vertical movement in the level of the sea. A tidal stream, on the other hand, even though it results from a tide, is a periodic horizontal movement.

Tides affect the depth of the water at a particular place. Tidal streams affect navigation courses.

Tides are affected by the solar cycle. Twice a month, first when the moon is new and again when it is full, *spring tides* will be experienced. This is when the highest *high waters* and the lowest *low waters* of a tide cycle occur. Seven-and-a-quarter days after the spring tide, with the first and last quarters of the moon, the *neap tide* occurs. This is when the lowest high waters and the highest low waters of a tidal cycle are experienced.

There are thus two separate tide cycles: height fluctuations from springs to neaps, which take place twice each in a lunar month (29 days); height oscillations of each tide from high water to low water, which take place twice each in a lunar day.

This is a basic description of the phenomenon of the tides. There are, of course, other factors to be considered. The fact that the orbits of the earth and the moon are ellipses and not circles must also be taken into account. These ellipses have a corresponding seasonal (equinox) effect on the height of the tide wave (astronomical tide). Wind and barometric pressure also exercise an uncertain influence on the tide wave. A wind blowing onshore usually tends to raise the height of a tide, while an offshore wind tends to lower it. A wind blowing in the same direction as the advancing tide wave crest tends to hasten the time of high water and a wind blowing in the opposite direction will delay it. The tidal range can be as little as 100 mm and as much as several metres. In most countries, tide tables are available from the hydrographic office or harbour office.

Tides are important factors in safe navigation. Navigators, whether of fishing boats or ferries, are continuously asking themselves "How deep is the water under my boat?"

To ensure safe navigation in and out of manmade ports, all depth soundings are referred to *chart datum*, or low water spring level, and all land heights are referred to high water spring level.

To record a tide table for a particular area or coastal village, all that is required is a simple tide gauge installed in a relatively calm place. A tide gauge can easily be made from a

Figure 22a
Tides

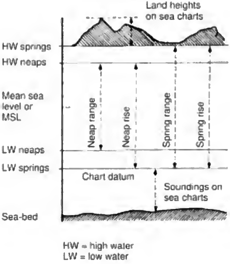
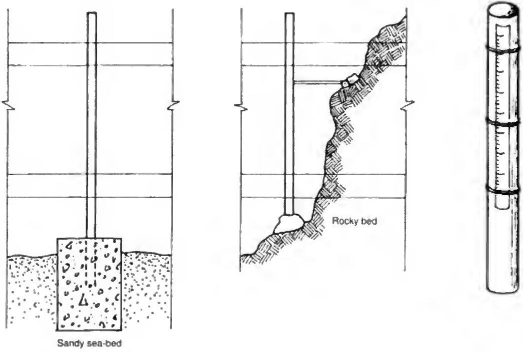


Figure 22b
Methods of measuring
tidal variations



piece of steel or plastic tube, or a piece of timber, with a length of plastic tape-measure tied to its side – a tailor's plastic tape is ideal for this purpose (Figure 22b).

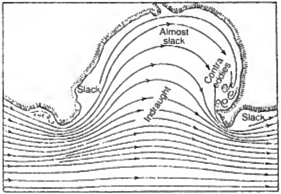
In a sandy location, the upright pipe or timber should be driven into an oil drum filled with concrete or stones. The whole contraption can then be buried in a suitably calm place where the tape can easily be read. In a rocky location, the pole or pipe should be concreted inside a hole in the rock. To install the tide board (in this case, the tape-measure), a surveyor equipped with a level and staff should be called in. By recording the level of the sea a few days before and after a new moon, the low water spring level can be deduced. This is the lowest point reached by the water level and the tide board can be installed by placing the zero mark of the tape at this level. The full tidal range can then be recorded. Once the tide board has been installed, the level of the sea surface should be noted every hour or so for a period of two months. It should be recorded in a table together with the time, date and weather conditions.

Tidal stream survey

The tidal phenomenon described above gives rise to tidal streams, which are periodic horizontal movements of the water. In open ocean this horizontal movement is either nonexistent or very small. In inshore and coastal waters, on the other hand, whenever there is an appreciable vertical movement, a horizontal movement can also be expected.

The main cause of tidal streams is a change in water levels. The average velocity of tidal streams depends on the average height of the advancing tide wave. In deep ocean this height is small so the stream rate is either very feeble or very small. Where the wave height is large the stream rate will be correspondingly great. When a tidal stream meets an obstruction to

Figure 23
The set and drift of the
tidal stream in and around a bay



its to-and-fro movement, its direction and velocity are affected. So, when a tidal stream meets a headland, it is deflected around it, and usually immediately off the headland the tidal stream's velocity is increased (Figure 23). Its direction is deflected round the headland into the bay beyond, and this causes an indraught of indefinite direction and velocity. The spreading out of the deflected tidal stream, combined with the fact that its real strength runs from headland to headland leaving comparatively unmoved water between headlands, causes diminished velocity in the bay itself.

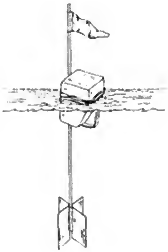
In the absence of tides, sea currents may be experienced during sea storms. These currents, although not as strong as tidal streams, should be observed closely because they usually carry weeds uprooted from offshore areas.

Currents in general make navigation more difficult but not impossible. When the currents bring with them seaweed or flotsam (including timber and vegetation carried down by rivers), navigation may be hindered by weeds fouling up propellers. Flotsam, or floating debris, may also prove troublesome if it is piled up inside a harbour by a prevailing tidal stream or sea current.

The strength of a current may be measured by timing it as it travels a known distance along the coast, or across a bay. A simple can-float with a counterweight hanging about 1 m below water level (Figure 24), can be used to do this. When measuring currents at sea, the following points should be observed:

- When the currents are storm generated, what are the general direction and duration of the storm or incoming waves?
- If seaweed appears, after how many hours of storm does it make its first appearance?

Figure 24
Simple can-float



- If flotsam or driftwood appear, where do they land? In many instances, one particular spot or bay may accumulate more debris than adjacent ones. Such spots or bays do not make good sites for harbours.

Wave height survey

The precise nature of the waves that occur on a particular stretch of coastline can be investigated in three different ways:

- On-the-spot measurement by special electronic equipment called a wave-rider buoy. This can be hired for a set time, from a private company or government laboratory, together with a trained operator.
- Prediction by statistical methods on a computer using statistical models. This can be done if wind data are available for the area.
- On-the-spot observation by simple optical instruments such as the theodolite.

The first two methods give very accurate results but are very expensive. These methods are usually reserved for big projects where precise wave data is of the utmost importance.

The third method is not very accurate but is relatively cheap and lies more within the scope of this booklet. The only differences between this method and the first method are the observer and recorder of data.

In the first method the observer is an electronic instrument that can record continuously far out at sea where the waves are not yet influenced by the coastline. In the last method, however, the observer is a normal surveyor observing waves close to the shoreline with a theodolite placed at a secure vantage point. The wave heights thus recorded will be distorted and suitable only for minor projects.

Setting up a wave observation point

The equipment needed to set up a wave observation point consists of two large fluorescent plastic buoys about 500 mm in diameter (one should be red and one white), a large stone or concrete sinker, a length of 10-mm nylon rope, a theodolite, a compass and a watch with a second hand or digital readout.

A vantage point that is just high enough above sea level to be safe and dry during a storm should be chosen. A stone pillar should be erected here with an anchor screw concreted in at the top. This is so that every time the theodolite is set up it faces the same way in exactly the same position (Figure 25).

Figure 25
Observation pillar in stone and concrete

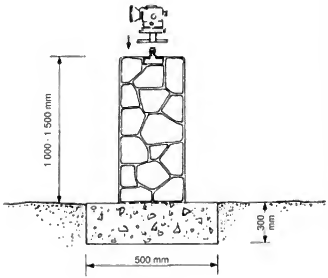
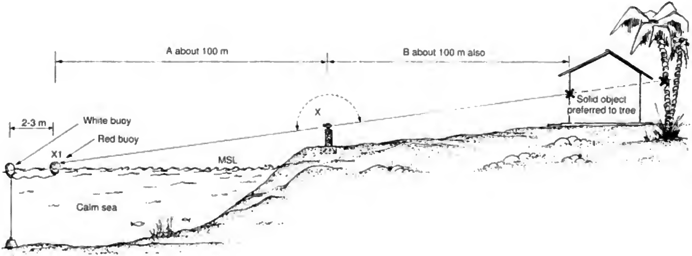


Figure 26
Set-up for a wave observation station



The two fluorescent plastic buoys should then be moored a known distance (say 100 m) offshore as shown in Figure 25. The white buoy keeps the mooring line taut while the red buoy floats freely on the incoming waves.

To calibrate the station, the theodolite should be pointed at the buoy on a very calm day. A witness mark should then be placed on something robust (a wall, for example, is preferable to a tree) so that the observer can repoint the eyepiece of the theodolite at the buoy in its rest position even when the buoy is bouncing up and down with the waves during a storm.

In this way the theodolite is not tied up completely with wave height observations but can be used for other work as well (Figure 26).

Figure 27a shows the view through the eyepiece of the theodolite with the base of the buoy just above the central hairline in perfectly calm conditions.

During a storm, the buoy will float up and down with the passage of the waves. By following the base of the buoy with the same central hairlines, the theodolite is made to traverse a small angle, Z, as shown in Figure 28. Using basic surveying principles, the distance between the theodolite and the buoy and the angle Z may be used to calculate the height of a wave. As a rule of thumb, a wave during a storm is twice the height of a wave in calm water. However, it must be emphasized that this calculation is very approximate and suitable for minor projects only. During wave height observations, the following additional information should also be recorded:

- The direction of both the incoming waves and the wind. These can be taken by using a hand-held compass.
- The time difference between each successive wave peak. This is also known as the wave period and is measured using the second hand on a watch.

Figure 27a
View through eyepiece of theodolite

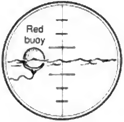


Figure 27b
View through eyepiece during the passage of incoming waves

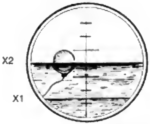
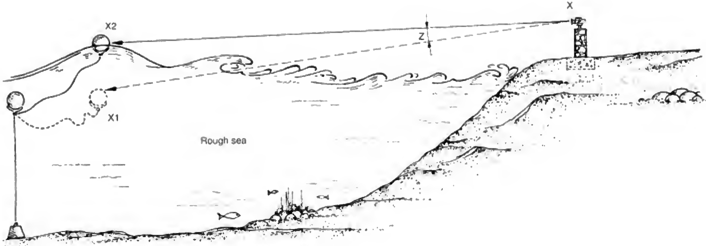


Figure 28
Observing incoming waves during a storm



- The exact position of the buoy with respect to the coastline.
- The time of year when each storm was recorded.

As mentioned earlier, this method is suitable only for small projects where the anticipated financial outlay is very limited. The method has several drawbacks that may be summarized as follows:

- The human observer can see waves during daylight hours only and this effectively reduces observation time by at least 12 hours a day.
- In very bad weather, strong winds and rain usually reduce visibility to only a few metres, making it difficult to keep the buoy under continuous observation.
- The presence of swell or long waves is very difficult to detect, especially during a local storm. This is because of the long time (15 seconds or more) between peaks.

Having completed the site survey, all the data collected should then be put on a drawing with the help of a surveyor.

Chapter 9 describes some of the ideal scales for layout drawings and some of the more common drawing conventions used.

Ideally, the layout of the site should include the hydrographic survey (in grid or contour form) and the area where the fishing shelter will be situated.

All forms of access and all landmarks should also be plotted on the layout. So should nearby utilities, such as fresh-water wells, water pipes and electricity, if available.

The tide, tidal streams and wave data should be drawn up in table form. Before embarking on the construction phase, however, it would be a good idea to show the drawing to an engineer from the public works office for comments and suggestions.

3. BUILDING A GOOD FISHING SHELTER OR LANDING

A good coastal fishing shelter normally consists of:

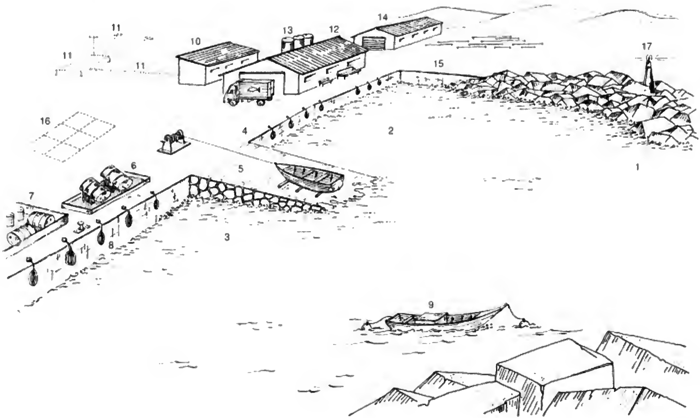
- A breakwater to protect the moored fishing vessels in rough weather.
- A quay along which to moor the boats when unloading the catch.
- A slipway where the fishing vessels can be scrubbed, painted and serviced.
- Various shore facilities.

Occasionally there will also be areas of land reclaimed from the sea to provide space for the activities associated with fishing. In some cases, such as at the mouth of a river or where there is an open beach landing, the breakwater is not needed.

These are typical fishing harbour installations (the numbers in brackets refer to the numbers on Figure 29):

- rubble breakwater, if necessary (1);
- fish-handling basin for offloading (2);
- boat-servicing basin for maintenance (3);
- quay wall with a minimum depth of 2 m (4);
- slipway with a simple winch (5);
- artisanal refuelling point (6);
- waste oil and slops disposal/separation facility (7);
- used car tyres recycled as fenders (8);
- tie-up area for boats waiting for spare parts(9);
- toilets and washrooms (10);
- landing/village sewage disposal (11);
- fish hall for sorting, packing, selling and icing fish, including ice store or small ice-plant (12);
- elevated fresh-water supply tanks (13);
- fishermen's net store, engine spares, hawker stalls and recreation areas (14);
- flat area set aside for net repair (15);
- parking area set aside for fishmongers if landing is close to a big market (16);
- aids to navigation (17).

Figure 29
Complete fishing harbour layout



BREAKWATERS

The purpose of a breakwater is to establish an area of calm sea where boats can be moored safely during rough weather. It is important for the local community that such a breakwater can withstand the pounding of waves that are normal for the area (that is not counting freak or rare storms). If a breakwater cannot stand up to normal conditions the fishing fleet may be badly damaged. To avoid this happening, particular care should be taken when a breakwater is being built with little or no direct help from the public works department. On rocky coastlines, breakwaters in depths exceeding 3 m should not be attempted without technical assistance. This is because waves in deeper water are difficult to predict. On sandy coastlines expert advice should always be sought, irrespective of how deep the water is.

The typical breakwater consists of a mound of coarse stone, known as a core, covered or protected by blankets or layers of heavier stones (Figure 30).

The core typically consists of coarse quarry waste, without fine particles of dust and sand. This is dumped in a heap into the sea by a dump truck. To make dumping by truck easier, the core should ideally be 4 – 5 m wide at the top and approximately 0.5 m above mean sea level or, when there is a large tidal range, above high water spring level (Figures 31a to 31c). The top of the core should be kept level and uniform by a bulldozer. This allows the dump trucks to travel the entire length of the breakwater while it is being constucted. When tipped into the water, the core rubble comes to rest at a slope of approximately 1 on 1 (sometimes written 1/1). This is a slope that drops down 1 m in height for every 1 m it goes forward. The rubble in the core is very light, so breakwaters should be built during calm seasons only.

Chapter 4 describes in detail the type of rock that is suitable for a rubble breakwater.

The first underlayer of stone (Figures 32a to 32c), which protects the core rubble from being washed away, usually consists of single pieces of stone whose weight varies from 500 kg to 1 tonnne (1 000 kg).

These stones are usually laid in a minimum of two layers at a slope that is shallower than that of the core; 2.5/1 on the outer slope and 1.5/1 on the inner slope. A slope of 2.5/1 means that the height of the slope drops 1 m for every 2.5 m it goes forward. The first layer of stone can be placed by a hydraulic excavator (Figure 32b and 32c). A normal crane may also be used if space for the outrigger pads is available. Rubber-tyred cranes should never be used on an uneven core without the pads in the extended position.

The excavator should place the heavier stone underlayer as quickly as possible so that the core rubble is not exposed to wave action. If a storm strikes the site when too much core is exposed, there is a grave danger of the core being washed away and spread all over the intended port area.

Figure 32a shows the set-up for a given stone profile. In this case the slope is 2.5/1 and the distance, H, is the height of the top of the underlayer above the sea-bed. A wooden pole should be placed on top of the underlying core and cemented into place with mortar. At a distance equal to 2.5 x H, a heavy stone sinker with a marker buoy should be placed on the sea-bed. A brightly coloured nylon string should then be strung from the sinker to the required height (H) on the pole. This procedure should be repeated every 5 m to help the crane or excavator operator to place the top-most layer at the correct level. A swimmer wearing goggles could ensure that each separate rock is placed within the profile outlined by the nylon string.

Figure 30
Cross-section of a rubble mound breakwater

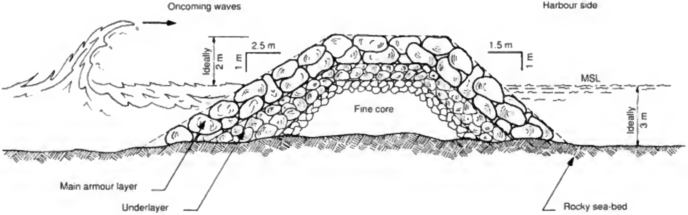


Figure 31
Placing the rubble core

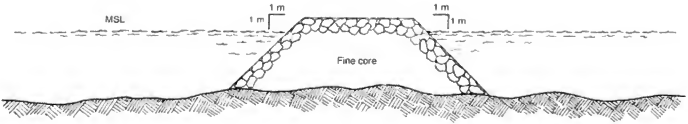


Figure 31a
Cross-section

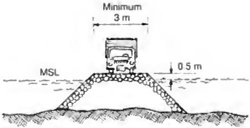


Figure 31b
Tipping by truck

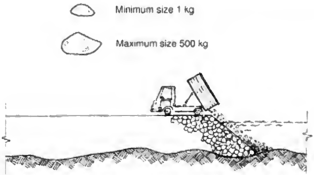


Figure 31c
Tipping by truck

Figure 32
Placing the underlayer

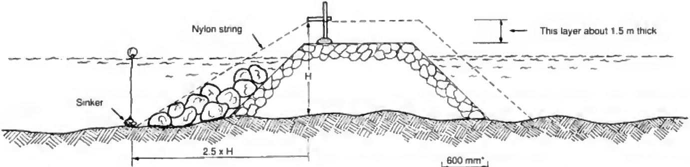
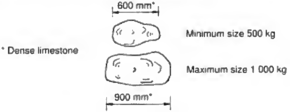


Figure 32a
Cross-section



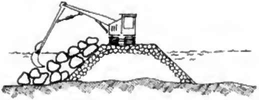


Figure 32b

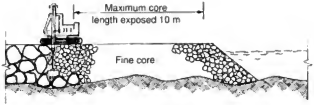
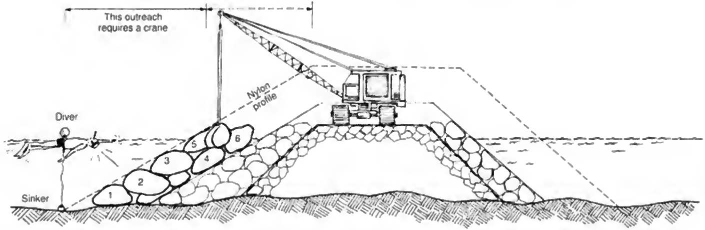


Figure 32c

The main armour layer, as its name implies, is the primary defence of the breakwater against wave attack. Any defects in the quality of the rock (see Chapter 4), in its grading (such as using rocks that are too small) or its placing (on a slope that is uneven or too steep) will seriously put the whole breakwater at risk. Hence great care must be taken when choosing and placing the stone for the main armour.

Figure 33 shows stone for the main armour being placed by



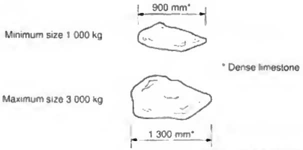


Figure 33
Placing the main armour layer

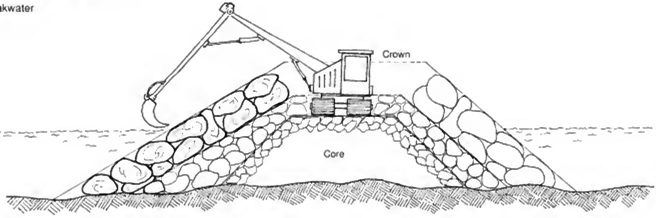
a crawler crane or tracked crane. Such a crane is by far the best equipment for placing large stones. The large stones should be lifted singly using a sling or grab. They should be placed in the water with the aid of a diver or of the crew of a boat equipped with a glass-ended tube. The armour layer should be placed stone by stone in a sequence that ensures interlocking. In Figure 33, for example, stone 2 is held in place between stones 1 and 3. Stone 4 is jammed between stones 3 and 5. This ensures that waves cannot pull one stone out, causing the upper stones to topple down the slope, breach the armour layer and expose the smaller rubble underneath.

To ensure that stones are properly placed, the swimmer or boat crew should direct the crane operator each time a stone is placed until the armour layer breaks through the surface of the water. As with the underlayer, two layers of armour stones are required to complete the main armour layer. Slope profiles should be set up at regular 5-m intervals using the same procedure as shown in Figure 32.

Figures 34a and 34b show how the nearly complete breakwater is closed off layer by layer.

It shows the excavator backtracking to the root of the breakwater and closing the top layers (or crown) as it does so.

Figure 34a
A hydraulic excavator placing the rubble on the crown of the breakwater

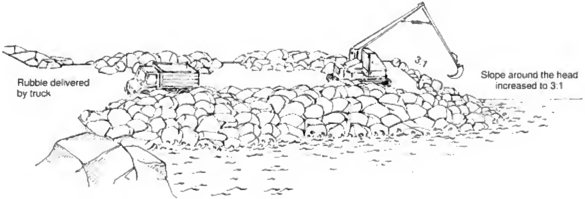


The end, or head, of the breakwater is the most delicate part and requires extra care. The outer slope of 2.5/1 should be increased to 3/1 to improve stability.

Other types of breakwater. The type of breakwater just described is known as a rubble breakwater because it is made of rubble placed in a special manner. This type of breakwater adapts itself very well to most conditions, especially to varying sea-bed depths; it can also sustain some damage from storms without completely breaking up.

A rubble breakwater, however, is not always suitable. When a rocky reef (not coral) already exists (Figure 35a), the ideal

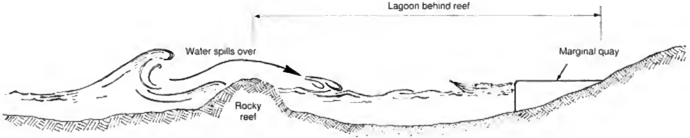
Figure 34b
The same machine backtracking and closing the crown at the same time



solution would be to raise the level high enough to prevent the breaking waves from spilling over the reef and on to the boats moored behind it. As mentioned earlier, an anchored solid breakwater should be constructed on the rocky outcrop. On the other hand, if the reef consists of living coral, the breakwater should be built inshore, if there is space for it, away from the coral.

Figure 35b shows a recess cut into the reef and a solid wall built from jute bags filled with concrete and placed in position. When the concrete has set, after about 24 hours, an *in*

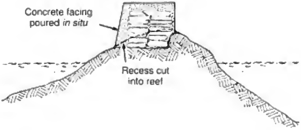
Figure 35a
Improving a lagoon basin

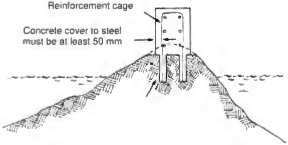


situ capping should be poured all round the bags to form a smooth-finished wall. Alternatively, a solid reinforced concrete wall should be built as shown in Figure 35c. In this case it is assumed that a compressor and an air-drill are available on-site for drilling anchor holes into the reef at, say 0.5-m intervals. The reinforcement should then be cast into the drilled holes using a very dry mortar mix.

Figure 35b
Building a higher wall with jute bags filled with concrete and capped

Figure 35c
Building a higher wall in reinforced concrete anchored to the rocky reef





QUAYS AND JETTIES

Within a harbour, a quay generally lies parallel to the shoreline and boats are moored along the sea-side only. A jetty generally sticks out into the harbour waters and allows boats to be moored on either side. In protected waters a stand-alone jetty may be all that is needed to make a satisfactory landing facility.

Quays. Quays can be either of solid construction or built on piles. A solid quay, suitable for areas where the sea-bed is rocky or sandy, is shown in Figure 36.

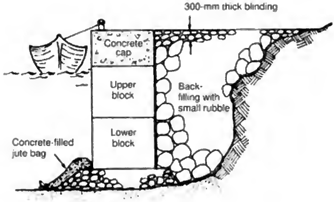
A piled quay (Figure 40) is more suitable in areas where the sea-bed is very soft, such as on riverbanks or in mangrove areas.

In areas where there are large tidal variations, the usual approach is to have a floating landing (Figures 44 to 46). A floating landing is also suitable on lakes, where water levels may vary from year to year by several metres.

Before embarking on a project, a careful study should be made of the type of plant available as this will influence the final cost of the structure. In Chapter 4 there is a description of the type and quality of materials that should be used for construction works in sea water. Chapter 6 gives a general description of the types of fittings used and their anchorage requirements.

The solid quay in Figure 36 has been built from concrete blocks laid, by crane, on a screeded bed of stone chippings or aggregate. The concrete blocks are cast on the ground. After 28 days (which is the standard curing period), they were lifted and placed in the water in a line to form the quay wall. Each vertical pillar of concrete blocks should not touch neighbouring pillars so that it is free to settle independently into the screeded stone bed.

Figure 36
Typical cross-section of a blockwork quay



To prevent the propellers of fishing vessels from scouring the screeded stone bed, concrete-filled jute bags should be placed at the base of the quay to cover the stone bed for the whole length of the quay wall. A diver is usually employed to carry out this operation. The pillars of blocks should break the water surface approximately 500 mm above mean sea level, where a concrete capping block is then cast to cover the tops of five pillars, joining them together. The capping block should contain all the holes and recesses for the quay fittings, such as fenders, bollards and mooring rings.

The area behind the quay wall should then be filled in with small rubble. No dust, silt, clay or mud should be used because this would leak out from the gaps between the block pillars and lead to settlement of the paving.

Figure 36a
Quay made of pillars of blocks

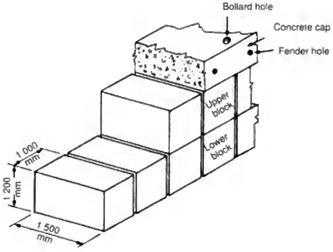
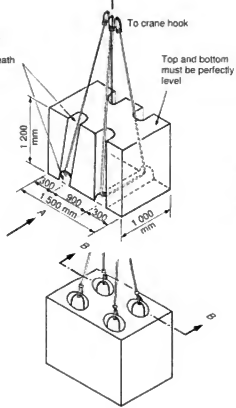


Figure 37
Typical block dimensions and lifting methods



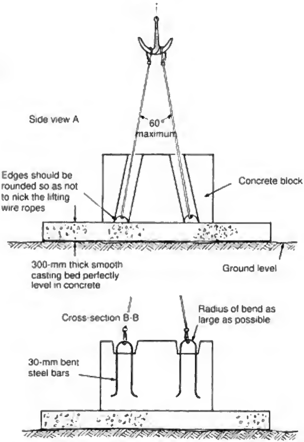


Figure 38
Preparing a screed foundation for a blockwork quay

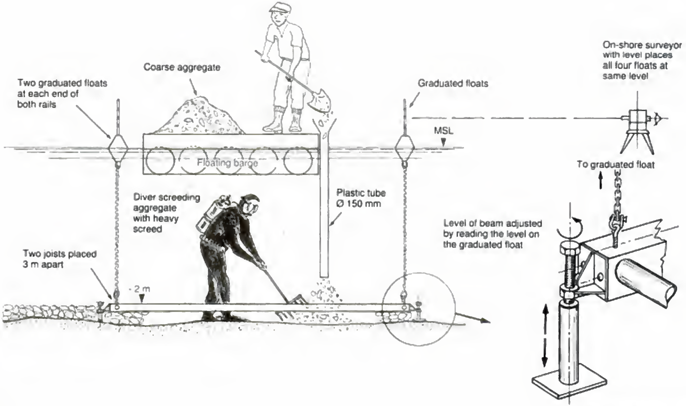


Figure 39 shows the cross-section of a solid quay which did not require the services of a crane during its constuction.

Instead of using uniform blocks of concrete, jute bags were filled with wet concrete and placed underwater by a diver. The screeded stone bed is not absolutely necessary in this case, but a layer of coarse aggregate is recommended. This increases the stability of the foundation layer against scour by boat propellers. Unlike the concrete block quay wall, this type of quay does not have to be screeded perfectly level. Obstacles, such as an uneven sea-bed or large boulders, can be included

Figure 39
Typical details of a shallow quay in jute bags

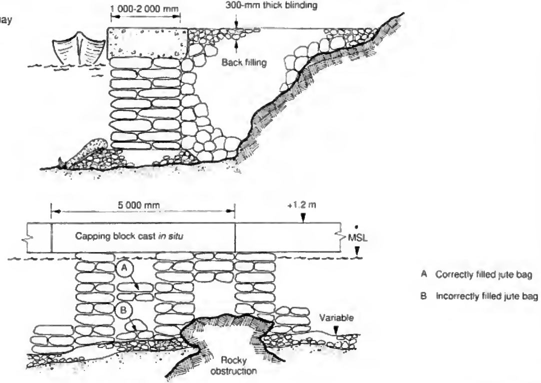
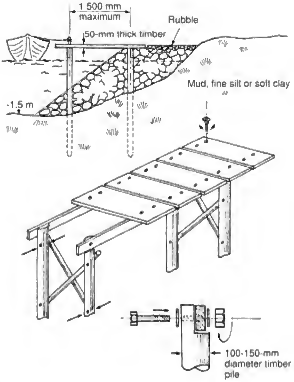


Figure 40
Piled quay



in the foundation, but if possible they should be removed or the quay wall diverted away from them.

The jute bags, once filled with concrete and stitched shut, should be placed in the pattern shown in Figure 39 to ensure a solid construction. Care should be taken not to overfill the bags; when laid flat and squeezed lightly, they should present a horizontal flat side on which to place the next layer of bags.

The quay wall should then be completed with a concrete capping block as described for the concrete block quay.

Figure 40 shows a piled quay suitable for a mud or clay shoreline. This kind of structure is fragile compared to the solid quay and should only be built in very calm areas.

Timber piles, 100 – 150 mm in diameter, should be driven into the mud using a pile driver similar to that shown in Figure 41.

The piles should be placed according to a 1 – 1.5-m grid depending on the size of the piles and timber beams available. The quay is then finished by anchoring timber beams from pile to pile along the length of the quay. Planks can then be attached to these beams to make a wooden deck.

If a quay deeper than 1.5 m is required, two such constructions should be built, one in front of the other. The distance between the piles should never be greater than 1.5 m.

Once the piles have been driven into the ground, the shore-side of the quay should be filled in with coarse quarry material. This will increase the stability of the quay and prevent rotting flotsam from being trapped between the quay and the shore.

All the timber used in this type of structure should be treated against borers as described in Chapter 4.

All metal fittings should be galvanized steel (steel that has been coated in zinc) or brass. Only countersunk screws and bolts are suitable.

Nails should not be used in any part of the deck.

Figure 41
Simple piling rig for soft clay ground

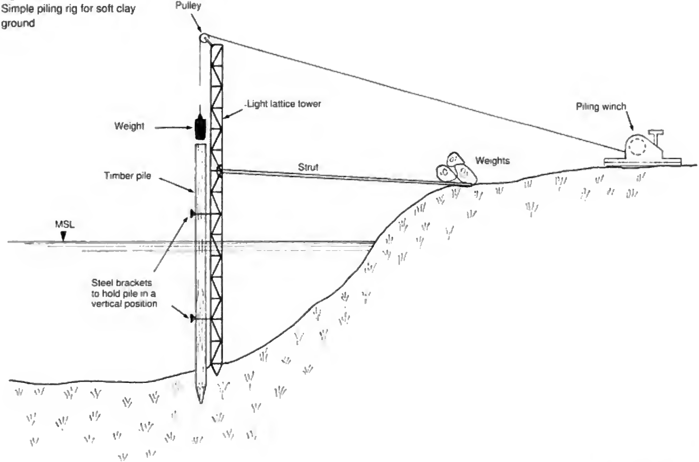


Figure 42
Two types of finger-jetty

Figure 42a

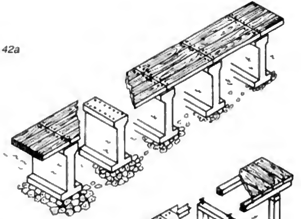


Figure 42b

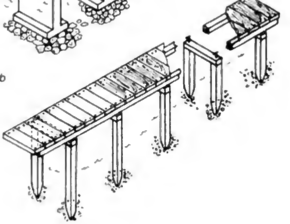


Figure 42 shows two typical concrete finger-jetties suitable for areas of relative calm, such as in sheltered tidal beaches or inside existing harbours.

If the concrete is made properly, a concrete jetty will usually outlast a similar one built in timber.

Figure 42a shows a jetty suitable for areas with large tidal variations where pylons of simple mass concrete (that is concrete with no reinforcement) can be cast on a gravel bed at low tide. Precast reinforced concrete or plain timber decking is then anchored across the pylons to form the jetty.

If a piling rig is available, precast reinforced concrete piles, 300 x 300 mm, can be driven into the sea-bed and beams cast across the pile heads as in Figure 42b. As for the pylon type of jetty, precast reinforced concrete or plain timber decking can then be anchored across the beams.

Chapter 4 gives details on the manufacture of durable marine concrete. Coral aggregate (stone and sand) is not suitable for steel-reinforced sections. All the steel reinforcement used inside concrete sections (piles, beams or slabs) should be covered by at least 50 mm of concrete. All exposed fittings should be galvanized.

Figure 43 shows typical land reclamation. Figure 43a shows land that has been reclaimed by tipper trucks full of quarry waste and Figure 43b shows land reclaimed by dredger, see Chapter 5.

When reclaiming land from the sea using dredged or mined sand, great care should be taken to avoid polluting the sea with suspended dust. Fill material contains very fine dust and reclamation projects often give rise to plumes of suspended sediment in the sea around the construction area. These are harmful to certain forms of marine life, such as coral, that need bright sunlight to survive.

Figure 43
Land reclamation

To prevent reclaimed material from leaching away into the sea it should be protected by geotextile filters (Figure 43c) of adequate porosity. The geotextile filter has to be anchored to the side of the reclaimed bank using weights (not pegs). The weights can then be incorporated into the retaining bank that consists of carefully placed stones weighing at least 500 kg.

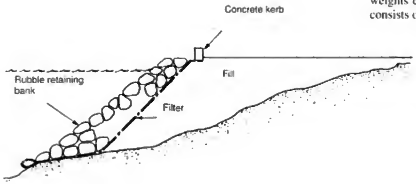


Figure 43a

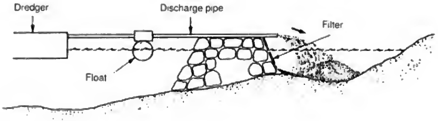
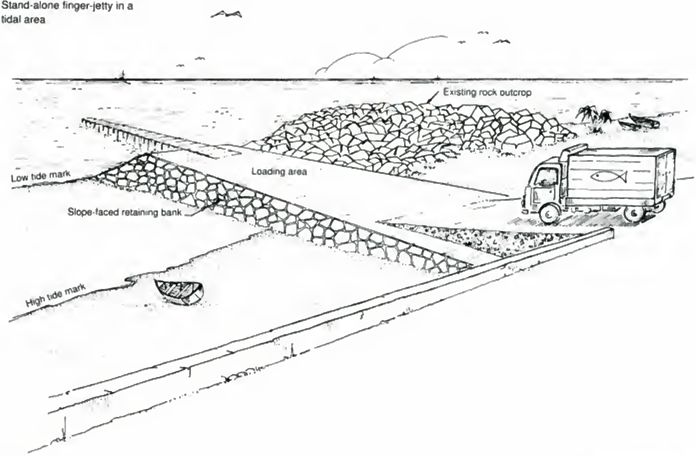


Figure 43b

Figure 43c

Figure 44
Stand-alone finger-jetty in a tidal area



Each patch of geotextile filter laid should either be stitched to or overlap the previous patch by at least 300 mm. Punctured filter should be repaired prior to being placed.

Figure 44 shows a stand-alone finger-jetty in a tidal area. The solid part of the jetty (the loading area) should not project beyond naturally occurring obstacles, such as rocky outcrops.

Figure 45 shows a floating platform anchored in position by four vertical piles and connected to dry ground by a gangway pivoted to a frame. The platform rises and falls with the tide.

Figure 46 shows a floating platform made from empty oil drums and timber sections. Chapters 4 and 8 tell you how to protect timber and steel that are immersed in water.

In areas where water-levels vary considerably over long periods of time, such as on lakes where water levels may take several weeks to change noticeably, a different anchoring system is required.

Figure 47 shows a floating platform for such conditions. It is held in place by four anchors and two "spuds" (steel piles). Two mooring lines run from the two anchors on land, pass over the platform, through a hand-operated winch and connect up to the remaining two anchors in the water. In this way the platform can be winched out as the water level drops and the shoreline recedes from its original position. The platform should be connected to the shore by a series of interconnected gangways that either float on the water or come to rest on the dry bed as the water level drops.

The platform should be equipped with at least two spuds to prevent it from swaying during high winds or strong currents. Each spud should consist of a heavy, pointed, steel pipe with holes drilled every 300 mm. Grips can be inserted in the right position to hold the platform steady as the water level changes. The spuds can then be lifted off the bottom until the

Figure 45
Floating platform landing

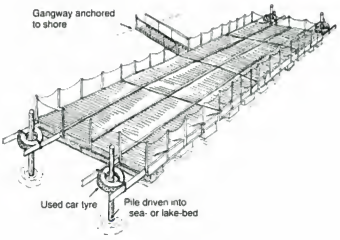


Figure 46
Float using oil drums

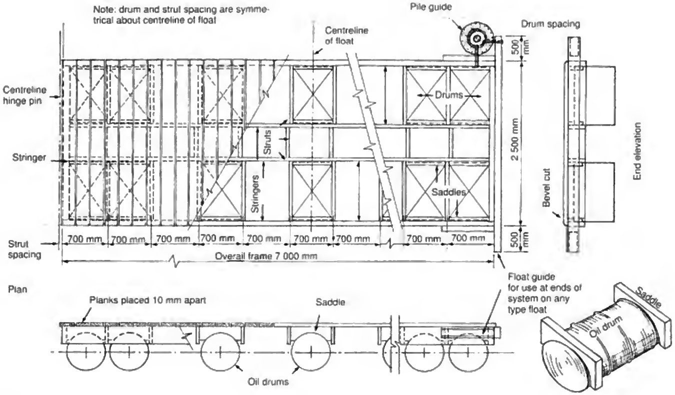


Figure 47
Floating landing

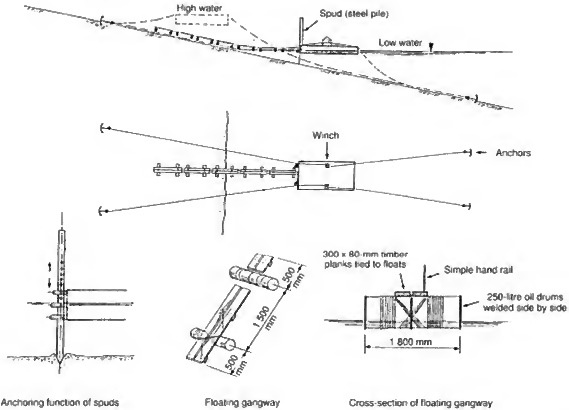
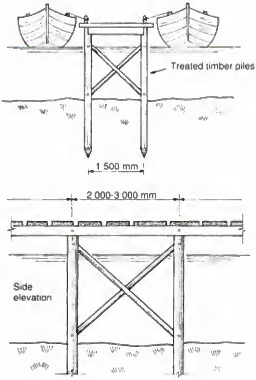


Figure 48
Timber finger-jetty



platform is repositioned in deeper water when they can be dropped again; their pointed tips will stick into the lake-bed, holding the spuds in position.

The anchors should be placed as far away as possible from the platform. The distance between the anchors and the platform should be at least five times the depth of the water below the platform. For example, if the water below the platform is 4 m deep, the anchors must be dropped at least 5 x 4 m away, that is 20 m away.

The anchors should preferably be made of steel and weigh as much as is possible to handle without the aid of cranes.

Figure 48 shows a typical timber finger-jetty on piles, with boats moored on both sides.

The piles can be made of timber, steel or reinforced concrete. Ideally, the deck should be built in timber or concrete.

SLIPWAYS

The traditional slipway in many small beach-side communities is still the natural beach where boats are hauled ashore for scrubbing, cleaning and repair. However, in a harbour or where there are no large tides, a beach is not always practical and a manmade slope or slipway is required.

In a harbour, a typical slipway consists of an opening in the quay wall over which a solid smooth surface is cast in concrete.

Ideally, the slipway should not be less than 5 m across and the slope not steeper than 10 percent (that is a slope of 1/10). The tip of the slipway should dip at least 1.5 m into the water as shown in Figure 49. To build a slipway, a bed of fine stone-chippings or gravel should first be laid to the required slope. From mean sea level up to the top of the slope, the slipway should be covered by a concrete cast in one slab, 300 mm

Figure 49
Typical cross-section of a slipway

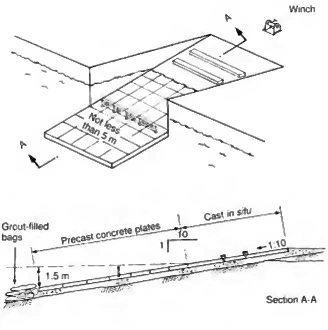


Figure 50
Precast slabs on a slipway

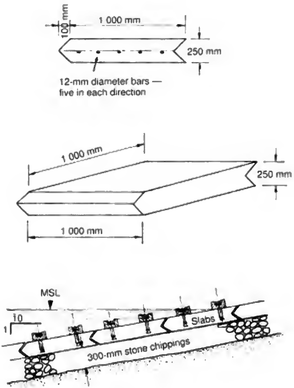
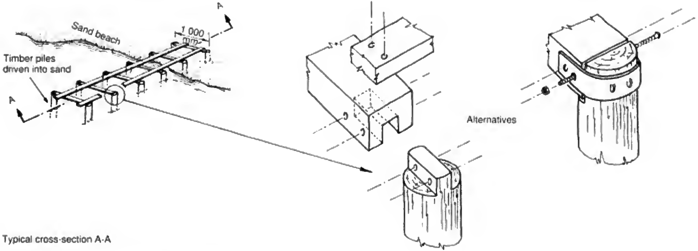


Figure 51
Beach slipway



Typical cross-section A-A

thick. From mean sea level down to the tip, the slipway should be covered in precast concrete slabs, at least 250 mm thick. The precast slabs should not exceed 500 x 500 mm and care should be taken to lay them evenly on the prepared bed of gravel. The tip of the slipway should be protected, against scouring, by concrete-filled jute bags. If boat trailers are not available for launching the vessels, timber sections of 150 x 150 mm should be laid down and bolted to the concrete slope to act as a rubbing surface for the boats' timber keels. Figure 50 shows the typical dimensions for the interlocking precast slabs required for laying underwater.

Figure 51 shows how a permanent slipway should be built on a sandy beach. Timber piles are driven in two straight lines at 500-mm intervals. Chapter 4 describes in detail the types of timber suitable for immersion in water. Wooden sleepers are then screwed into the piles with heavy-duty screws in stainless steel or brass. Light rails or timber runners should then be attached to span across the sleepers for a trolley to run up and down the slipway.

To haul the vessels up the slope, a hand operated 1 – 2-tonne winch is usually sufficient. The winch should be bolted to a block of concrete (separate from the slipway slab) at least 500 mm thick.

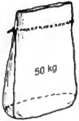
4. WHICH CONSTRUCTION MATERIALS TO USE

The basic construction materials required for marine work are: cement; aggregates (sand and stones); reinforcing steel; rubble; timber or steel piles; fastenings; timber wales or sections; and some other minor items.

Cement is a green-grey powder that sets hard within a few hours after the addition of water. It therefore acquires strength with time. There are many types of cement available on the market, the most common type is known as ordinary Portland cement (OPC). The most suitable type of cement for marine works, however, is sulphate-resisting cement (SRC). Cement usually comes in paper bags containing 50 kg of cement each.

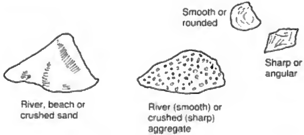
To make good concrete individual pieces of stone should be bound with a cement paste to produce a mix as dense and non-porous as possible. The aggregate (both the sand and the stone) has to be hard for the concrete to be durable. Good aggregate is so hard that it can only just be scratched by a steel penknife. Concrete made with soft coral stone is not durable and will disintegrate.

Figure 52
Cement



Pieces of crushed aggregate are angular in shape whereas river or beach gravel is rounded. Aggregate obtained from the sea will contain salt which is harmful to concrete. Sea aggregate must, therefore, be washed repeatedly with fresh water before being used in concrete. Coral aggregate should be used only as a last resort and then only if environmental conditions permit the harvest of living coral.

Figure 53
Aggregate



The most reliable source of stone rubble for construction is the quarry. A quarry is usually worked for a whole range of sizes of stone and the yield of the right sizes depends on the capability of the person carrying out the blasting as well as on the geological composition of the ground. As with aggregate, the durability of the concrete depends on the hardness of the stone. Again, as a general rule, a steel penknife should just be able to scratch the stone. If the stone scratches very easily, it is not suitable for breakwaters, quays or any structure in contact with sea water and a supply of harder stone should be sought.

Reinforcing steel is used inside a concrete section to make the section stronger. In marine work, the steel should have a minimum concrete cover of 50 mm to prevent sea-water corrosion.

Steel bars for reinforcing concrete come in a range of diameters, from as little as 6 mm up to 32 mm. Steel bars are usually supplied by weight, in kilograms per length of bar.

Figure 54
Rubble

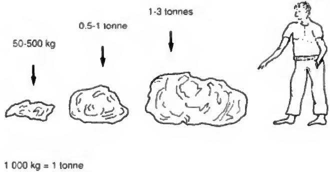
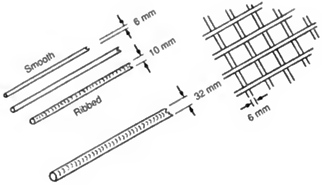


Figure 55
Steel reinforcement, bars and welded mesh



The most commonly used sizes are:
6-mm diameter, 0.222 kg/m;
8-mm diameter, 0.395 kg/m;
10-mm diameter, 0.617 kg/m;
12-mm diameter, 0.888 kg/m;
14-mm diameter, 1.208 kg/m;
18-mm diameter, 1.998 kg/m;
20-mm diameter, 2.466 kg/m;
24-mm diameter, 5.551 kg/m.
Bars are seldom more than 12 m long.
Reinforcement is also available as welded steel mesh.

HINTS ON GOOD SITE PRACTICE

Just as a good cook knows how to store ingredients to keep them fresh, careful housekeeping on the construction site will ensure that building materials remain suitable for construction purposes:

- Cement should not be stored on-site for more than six weeks. It should be used as quickly as possible.
- Cement and steel should be stored about 150 mm off the ground and covered by waterproof sheets tied down to pegs (Figure 56).
- Enough space should be left under the sheets for air to circulate. This prevents water from condensing on to the cement bags.
- Cement from punctured bags should not be used for construction.
- Cement and steel should not be stored in places where water collects in puddles after rain.
- If rain is forecast for the day, concrete work should be postponed.
- Cement, cement paste and fresh concrete should not be touched with bare hands. Cement in any of these forms may crack bare skin and lead to bleeding and infection.

In marine construction frequent use is made of piles in either steel, timber or reinforced concrete (Figure 57).

Figure 56
Cement and steel storage

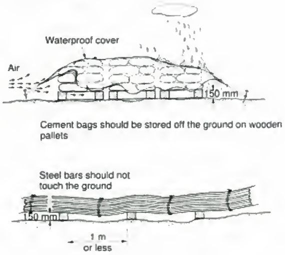
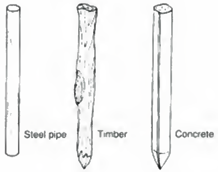


Figure 57
Piles



Piles are necessary when the ground is very soft (as in a marsh or swamp or on a muddy river-bed). In these cases a number of piles are driven into the ground to form a stable foundation.

To avoid deterioration, all piles must be protected: steel piles should be painted with special epoxy paints, timber piles should be treated with creosote oil and concrete piles should be made with sulphate-resisting cement (SRC).

Fastenings are required for holding timber sections together.

Depending on the size of the timber sections, the fastenings used can be either bolts or screws. Nails should not be used, because when they corrode they snap suddenly without warning.

Figure 58
Fastenings

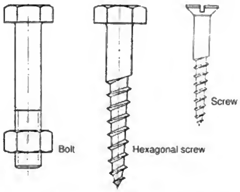


Figure 58a *Figure 58b* *Figure 58c*

Figure 58a shows a hexagonal bolt which must be made of either galvanized steel or, better still, of brass or stainless steel.

Figure 58b shows a heavy-duty hexagonal screw, again made of brass or galvanized steel.

Figure 58c shows a normal countersunk screw which is also available in brass.

WHAT CONSTITUTES A GOOD CONCRETE MIX?

Nowadays, the basic construction material is concrete. The science of mixing the ingredients to make concrete is called mix design.

A proper mix is one that produces a dense and strong concrete that is durable and resistant to the elements. Such a mix is a balanced recipe composed of cement, fine aggregate (sand), coarse aggregate (stone) and fresh water.

Cement. As described earlier, the cement should be OPC or, better still, SRC. In any case it should not be older than six weeks.

Fine aggregate. Sand should be either washed beach-sand or crushed aggregate from a nearby quarry. Whichever is used it must be free from excessive quantities of silt and dust.

Coarse aggregate. The pieces of stone aggregate should not be larger than 50 mm each. They must be hard, non-porous and free from excessive quantities of dust. Coral should not be used for aggregate because it is too soft, porous and contains sea-salt which is harmful to steel reinforcing bars.

Water. The water used in the concrete mix should be clean, fresh drinking water free from any impurities such as salt.

Proportions of cement and aggregates

The proportion of cement to aggregate depends on the strength, impermeability and durability of concrete required. Experience has shown that a concrete mix of 1:2:4 (that is, for every one part of cement used, two parts of sand and four of stone aggregate are used) is suitable for general construction purposes in terms of both cost and strength. Workable mixtures that are richer in cement, for example, a 1:1:2 mix, are much stronger but more expensive because of the higher cement content.

Instead of simply using a rich mixture it is generally more economical to obtain the necessary quality of concrete by careful grading and mixing of the aggregates and water in a normal 1:2:4 mix.

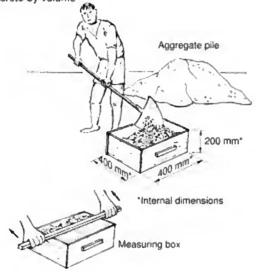
The 1:2:4 concrete mix by weight. Using a standard 50-kg bag of cement as the base measure, a 1:2:4 mix by weight contains 50 kg of cement, 100 kg of sand and 200 kg of stone aggregate. However, as it is not always possible to weigh such large amounts of aggregate, an equivalent mix by volume may be used.

Equivalent mix by volume. To every 50-kg bag of cement, 0.07 m^3 of sand and 0.14 m^3 of stone should be added.

Mixing by volume. To mix the materials, a wooden measure box should be constructed with inside dimensions of 400 mm x 400 mm x 200 mm (Figure 59). Sand or coarse aggregate can then be shovelled into the box and a straight edge run over the top as shown in Figure 59.

Each such level box contains 0.035 m^3 of sand or coarse aggregate. Therefore, a 1:2:4 mix is equivalent to:

Figure 59
Mixing concrete by volume



One standard 50-kg bag of cement
plus
Two box measures of sand
plus
Four box measures of coarse aggregate.

Depending on the size of the concrete mixer, the batching or mixing should follow these proportions. So, if the mixer is big, for every two bags of cement, four boxes of sand and eight boxes of stone should be added.

Adding water

The strength and workability of concrete depend to a great extent on the amount of water used in mixing. For each mix there is an optimum amount of water that produces the concrete of greatest possible strength.

If less water is used the workability of the concrete decreases and it becomes too stiff to work. Using more than the optimum amount of water increases the workability of the concrete (by making it more fluid) but decreases its strength and durability.

The optimum amount of water is influenced by:

- The origin and quality of the aggregate; concrete with porous aggregate requires more water than normal.
- The amount of silt or dust in the sand.
- The humidity of the aggregate; if the aggregate was exposed to rain the previous day then less water is required.

The best way of calculating the optimum amount of water required to make the strongest possible concrete is to carry out trial tests by adding water bit-by-bit to the mixer and testing the concrete as follows.

Figure 60
Testing the workability of fresh concrete

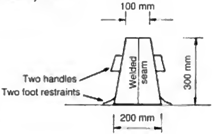


Figure 60a
Testing cone

Figure 60b
Filling the cone with fresh concrete

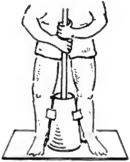


Figure 60c

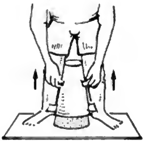


Figure 60d

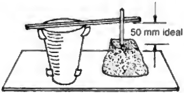


Figure 60e
Measuring the slump

First, construct an open-ended truncated cone from a piece of smooth, thin sheet-metal, following the dimensions shown in Figure 60a. Ideally, the seam of the cone should be welded vertically down one side and two handles should be welded to either side; one pair of handles near the top and one near the bottom of the cone. The inside should then be rendered very smooth. Remember that the inside should be kept well-oiled to prevent it from rusting.

When just enough water has been added to the concrete mixer to make the concrete appear wet but stiff, the cone should be filled with three layers of concrete, each compacted by hand using a steel bar 20 mm in diameter. The top should then be trowelled level and the cone lifted off. As soon as the steel cone is lifted off, the concrete will slump or settle down as shown in Figure 60. The ideal slump for most practical purposes is 50 mm, that is, the top of the concrete cone will sink 50 mm.

Should the concrete not slump by 50 mm, a bit more water should be added to the mixer and the whole test repeated until the slump reaches 50 mm. Water should be added 0.5 litre at a time by means of a measuring can and not directly with a water hose. See Annex 1 for tips on the handling and placing of concrete.

TIMBER

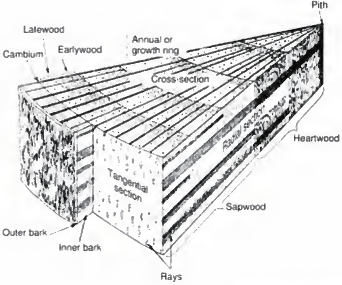
Timber is cut from trees, which are the products of nature and time. Humans have found timber to be a cheap and useful material and continue to use it in vast quantities. However, serious environmental problems can be caused by the overuse or misuse of nature's most important products. Unlike many of the other materials used in construction, timber cannot be manufactured to a particular specification. So, the best use has to be made of the material that already exists.

Durability is defined here as timber's ability to resist attack from salt-water, corrosion of metal fastenings, fungi and insect attack.

A tree trunk consists of two distinct sections; the inner section, or heartwood, and the outer section, or sapwood (Figure 61).

In some hardwoods, the sapwood is characterized by vessels or pores of large diameter, and only a few fibres are present.

Figure 61
Cross-section of a tree trunk



In the heartwood, the pore diameter is considerably smaller and the bulk of the tissue comprises fibres. Therefore, only heartwood, with its low porosity, is suitable for marine work.

Marine-borers

Timber used in sea or brackish (salty) water is subject to attack by marine-boring animals such as the shipworm and the gribble (Figure 62). Marine-borers are widely distributed, but they are particularly destructive in tropical waters. Most timbers have to be specially treated to protect them from marine-borers. Figure 62 shows how the gribble and the shipworm, or Teredo, destroy timber structures.

Some timbers, however, are naturally resistant to marine-borers. Some particularly resistant types of timber grow wild in tropical rain forests. Tropical rain forests, however, are a non-renewable source of timber that is fast disappearing. They should, therefore, be protected from exploitation and preference should be given to species grown in plantations, which are a renewable source. Table 1 lists some marine-borer resistant timbers and the continents where they grow.

As well as being very dense and only very slightly porous, the heartwood of these species secretes toxic substances which protect it from marine-borer attack. It can therefore be used untreated for marine piling and jetty construction.

Table 1
Marine-borer resistant timbers

Continent	Source	Common name
Africa	Plantation	Opepe
Asia	Plantation	Teak
Australia	Indigenous	Ironbark
Australia	Plantation	Southern blue gum
South and Central America	Rain forests	Greenheart
	Rain forests	Red louro

Figure 62
Damage to timber piles by borers

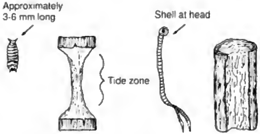


Figure 62a
Wood gribble and the "hour glass" effect it causes on piles

Figure 62b
Teredo shipworm and an internally bored pile

On the other hand, the sapwood of the above species is more porous and lacks the protective toxic secretions.

For marine work it is always advisable to use timber that has been impregnated under pressure with preservatives. Suitable preservatives are coal-tar creosote, creosote/coal-tar solutions and copper/chrome/arsenic waterborne mixtures. Experience has shown that when timber is thoroughly impregnated with one of these preservatives it will last a very long time. For this reason it is best to choose a timber that is easy to treat. The treatment should be repeated by dipping after the sections have been cut and holes drilled into them.

Environmental conditions and timber resources vary from place to place, so advice should be sought from the nearest forest products commission or office regarding the most suitable renewable timber to use.

Durability

Durability in marine work is defined in the broadest sense. The decay resistance of most timbers varies a great deal and even pieces cut from the same tree will often show wide differences. However, timbers have been classified into five broad grades, based on the performance of their heartwood in contact with the ground:

- *Very durable* timber will not start to decay until it has been in contact with the ground for more than 25 years.
- *Durable* timber will last for 15 to 25 years.
- *Moderately durable* timber lasts for 10 to 15 years.
- *Non-durable* timber lasts for 5 to 10 years.
- *Perishable* timber decays within five years.

Timber in direct contact with sea or brackish water (jetty piles for example) should be heartwood of one of the species listed as very durable, opepe or ironbark, for example (Table 2).

Table 2
Durability of different timbers

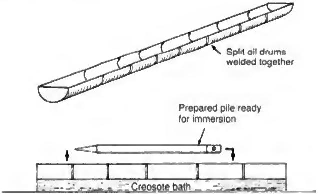
Moderately durable *(10-15 years)*	Durable *15-25 years*	Very durable *(over 25 years)*
Hardwoods		
Oak	Agba	Afrormosia
Sapele	Idigbo	Afzelia
Seraya	Mahogany[1]	Ekki
Walnut[2]	Oak[3]	Greenheart
Mahogany[4]	Chestnut	Iroko
		Jarrah
		Makore
		Opepe
		Teak
Softwoods		
	Larch	Pitch pine
	Douglas fir	Yew
	Pine[5]	Western red cedar

Notes
[1] American
[2] European and African
[3] European
[4] African
[5] Maritime
Remember that all sapwood is perishable, unless treated. Only the heartwood of the species in the last column is naturally resistant to marine-borers.

Timber used externally but not in direct contact with sea or brackish water (the jetty deck, for example) may be durable or moderately durable, such as oak, chestnut, Douglas fir or maritime pine, which has been treated with a preservative.

A bath for dipping timbers into preservatives can be made from a series of oil drums split in half and welded together (Figure 63). The timber sections to be treated should first be cut to the required size and bolt holes drilled at the appropriate points. Each section should then be immersed in a bath of preservative, such as coal-tar creosote, for at least 24 hours. After the required treatment, the timber should be allowed to dry before handling.

Figure 63
On-site treatment by dipping



5. USEFUL CONSTRUCTION EQUIPMENT

There are several types of equipment available for marine construction. The high cost of buying this equipment, however, puts most of it beyond the reach of village cooperatives, artisanal contractors and small general building contractors.

In this book it is assumed that most of the heavy plant will be available through the government or public works department or from local contractors. When planning a marine related project, it is useful to know in advance what type and size of construction plant is available in the vicinity of the village or landing.

Figure 64
Crawler crane

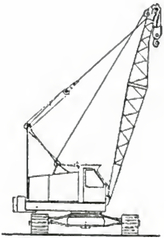
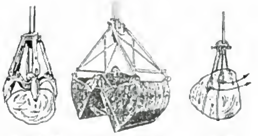


Figure 64 shows a typical crawler crane. As its name implies, a crawler crane crawls forward on steel tracks. This is the ideal type of crane for building breakwaters because it is very stable, requires no outriggers (the stabilizers that extend from the crane chassis of rubber-tyred cranes) and is unlikely to bounce off an uneven rubble surface into the water. The most important characteristic to consider is the nominal lifting capacity. This dictates the maximum outreach that the crane can handle with a given jib size.

Figure 65 shows some of the lifting attachments that can be hooked-up to a crawler crane:

- A rock grapple is used to pick up and place heavy pieces of rock.

Figure 65
Lifting attachments



• A clam-shell is used to dredge the sea-bottom. Most clam-shells have a soft metal (usually lead) lip to make them as watertight as possible. Without this lip, the clam-shell will leak and cannot be used to dredge fine sand, silt or mud. A clam-shell should not be used to place rocks on a breakwater.
• The sling in Figure 65 has a quick release attachment that enables the crane driver to open the sling and release a large rock underwater.

Figure 66 shows a crawler crane with a drag-line attachment. A drag-line consists of a sliding bucket that is dragged along the ground or sea-bottom for dredging.

The drag-line used to be the standard form of near-shore dredging until the hydraulic excavator (a far smaller machine that is more compact to transport over long distances) made its appearance.

Figure 67 shows a typical hydraulic excavator. This machine is very adaptable and now forms the backbone of most marine work.

Most makes of hydraulic excavator have interchangeable buckets and forearm lengths; for normal marine work a long forearm is required to reach as faraway as possible.

Hydraulic excavators can also be mounted on special barges (Figure 69) to act as dredgers, in which case a large bucket should be attached to the forearm.

Figure 66
Drag-line

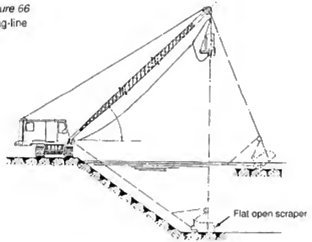


Figure 67
Hydraulic excavator

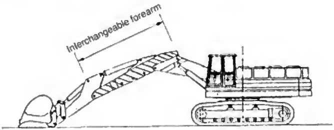


Figure 68
Cutter-suction dredger

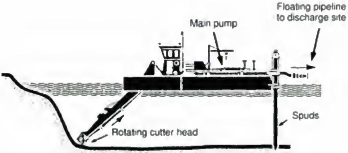


Figure 68 shows a typical cutter-suction dredger. A cutter-suction dredger consists of a rotary cutter coupled to a suction pipe. The cutter cuts through soft rock (such as coral) and the suction pipe draws the broken rock through pipes and discharges it some distance away. This piece of equipment is very costly and should only be used when a lot of dredging is required. A dismountable cutter-suction dredger can be broken down into four or more pieces for transport, but it has no propulsion and has to be assisted by a tug boat or fishing boat.

Figure 69
Barge-mounted excavator

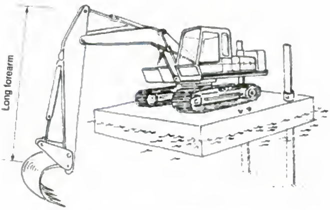


Figure 69 shows a hydraulic excavator mounted on a steel pontoon. This combination of equipment is ideally suited for shallow excavations and general marine work. Before choosing or building a pontoon for a particular excavator, an experienced engineer should make stability calculations. These will determine whether or not the barge is suitable for the size of the excavator. Stability calculations will also help to decide the number and type of lashings needed to hold the excavator in place. The excavator should not be operated without first being lashed down securely to the pontoon deck. A second vessel or open barge is usually required to collect the dredged material and haul it away from the excavator.

Figure 70
Bulldozer

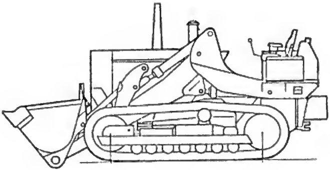


Figure 70 shows a typical bulldozer that comes with either a bucket or a simple blade. This kind of machine is essential when building a breakwater by dumping rubble at sea because the core material of the breakwater is kept level when using a bulldozer.

This brings us to the end of the list of the most common types of machine required for marine construction. A special point to notice is that all of these machines run on tracks and not on rubber wheels. It is good practice to rinse the tracks with fresh water at the end of a working day if they have come into contact with sea water.

If heavy-duty tipper trucks are not available, normal agricultural tractors and trailers (Figure 71) may be used for delivering rubble, aggregate or sand to a construction site. Considerably more labour is required than when tipper trucks are used, but at local village level finding extra workers is not usually difficult. The trailers should preferably be made of steel protected on the inside with timber planking. The timber prolongs the life of the trailer by absorbing the impact of individual stones thrown on to the trailer. With any rubber-tyred vehicle, care should be taken when crossing the uneven surface of a rubble core.

Figure 71
Tractor and trailer or truck equivalent

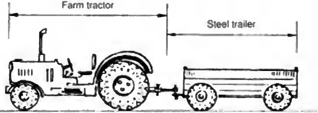
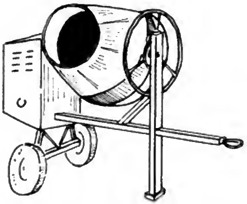


Figure 72
Petrol-driven concrete mixer



If possible, concrete should always be mixed in a proper concrete mixer. Concrete mixers come in various sizes. For normal village-level use, a small mixer like the one shown in Figure 72 should be purchased. Such mixers run on either a petrol- or diesel-driven engine and, if maintained properly, provide many years of trouble-free use. Extreme care should be taken to ensure that all traces of set concrete are cleaned off the mixing drum. Pieces of old, set concrete impair the efficiency of the mixing operation of fresh concrete.

Figure 73 shows a range of equipment that may be worth purchasing and keeping for general village use:

- A small diesel-driven air-compressor can be used to power a number of air-tools such as chisels, drills, hammers, saws and pumps. A compressor usually supplies about 5 000 litres of air per minute. For marine work, air-driven tools are safer to use than electric-powered tools.
- A portable diesel-driven generator and welding unit will supply about 12 KVa.
- A petrol-driven concrete vibrator with a 60-mm diameter vibrating needle is indispensable for all types of concrete work.
- A petrol-driven compactor is used for compacting pavements and road-beds.
- A piling winch or rig comes with a drop-weight that can be released quickly for pile-driving purposes.

Another useful item of equipment is an oxyacetylene cutting torch consisting of an oxygen and an acetylene cylinder mounted side-by-side on a portable frame. Two oxygen cylinders are usually required for every acetylene cylinder.

Figure 73
Equipment for general village use

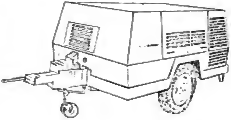


Figure 73a
Air compressor

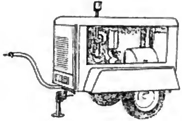


Figure 73b
Generator and welding set

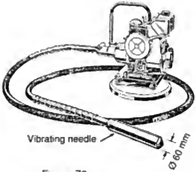


Figure 73c
Concrete vibrator

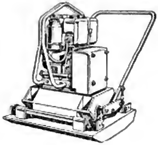


Figure 73d
Compactor

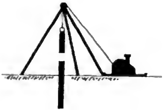


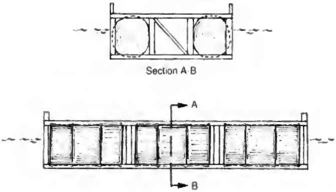
Figure 73e
Simple piling winch

Figure 74 shows a floating platform constructed from used oil drums. Floating platforms can also be constructed from timber with plastic drums as additional floats.

If a welding generator is available on-site, a welded steel platform on oil drums can be constructed.

Platforms are used to transport materials and light machinery to inaccessible places. Chapter 8 tells you how to protect steel from corroding.

Figure 74
Floating platform



6. FITTINGS, SERVICES AND NAVIGATION AIDS

Once the breakwater and quays or jetties have been built, various minor mechanical components are required for the shelter to function efficiently and safely. These components may be divided into three main groups according to their function inside the harbour:

- mooring fittings;
- shore facilities;
- navigation aids.

The mooring fittings include bollards, tyre fenders and mooring lines and sinkers.

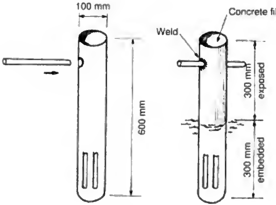
Shore facilities include the refuelling station, the slipway winch, the fishermen's rest and net lofts and, possibly, a market stall and toilets.

Navigation aids consist of the two marine lanterns (one red and one green) placed at the entrance to the fishing shelter. Other lights may also be required to indicate navigation channels or dangerous reefs.

FITTINGS AND SERVICES

Figure 75 shows a simple method of constructing a steel bollard that can then be cast in concrete. Two holes should be cut in a basic 100-mm diameter steel pipe. The holes must be big enough to allow a steel bar, 20 mm in diameter, to pass right through. The lower end of the pipe should then be slotted as shown to increase its grip inside the concrete. Once the bar has been inserted through the holes, it should be held in place by a spot weld on either side. The pipe should then be filled with concrete and the bollard inserted in the fresh concrete leaving about 300 mm exposed.

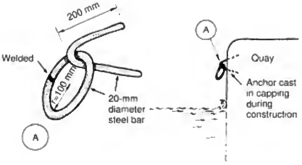
Figure 75
Simple pipe bollard



Remember that all types of shore-moorings made from steel (such as pipe bollards and mooring rings) should be protected from corrosion.

Chapter 8 gives information on various ways of protecting metal from corrosion.

Figure 76
Mooring ring

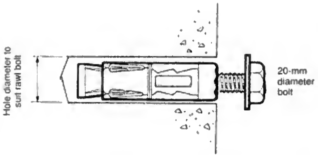


The mooring ring is a cheaper alternative to the steel bollard. It consists of a length of 20-mm steel bar bent into a ring and welded. The ring is held in place by a bent steel bar, as shown in Figure 76. The main advantage of mooring rings over bollards is that they keep the quay free of obstacles. Both bollards and mooring rings should be placed not more than 5 m apart.

Whenever possible, fenders should be fitted to the capping of a hard quay to prevent damage to moored fishing vessels. Anchor bolts are needed to fix the fenders to the quay.

There are two kinds of anchor bolts. One kind is used for quays that are already finished, where the concrete capping block is already in place. The other kind is for new capping blocks that are about to be cast.

Figure 77
Anchor bolts (drilled)



The first kind of anchor bolt is the rawl bolt (Figure 77) which can be bought from a good hardware store. A hole should be drilled into the existing concrete capping block and the bolt inserted into the hole. The friction grip is activated by tightening the bolt. For use in or near sea water a minimum bolt diameter of 20 mm is recommended to compensate for the effects of corrosion.

Figure 78
Anchor bolts (cast in place – lengths are in millimetres)

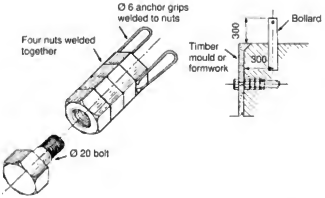
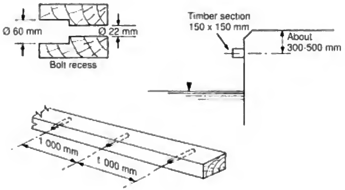


Figure 79
Continuous timber fender

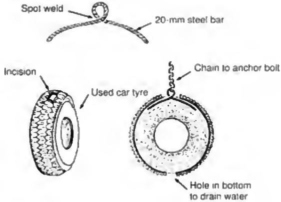


The second type of anchor bolt is cast in the concrete capping block during construction. To build this kind of anchor bolt, four 20-mm diameter nuts should be welded together and 6-mm diameter anchor grips welded to the nuts, as shown in Figure 78.

The position of the anchor bolt should then be marked on the outside formwork (also called a mould) and a 22-mm diameter hole drilled through the mould. The anchor can then be held in place by bolting it to the formwork and casting concrete round it. Once the formwork is removed, a neat, clean hole in the concrete presents itself and the bolt can be inserted into this.

The simplest type of fendering is the continuous strip of timber, shown in Figure 79. It consists of a strip of timber, about 150 mm x 150 mm, running along the whole length of the quay. Provided that it does not enter into contact with sea water, any kind of strong timber can be used as long as it is treated as described in Chapter 4. The timber strip should be held in place by 20-mm diameter bolts drilled at 1-m intervals. If the tidal variation is over 1 m, vertical strips of timber should also be attached every metre or so along the quay. The lower ends of these vertical strips will always be immersed in water at high tide, so only suitable timbers should be used.

Figure 80
Individual fenders



Old car tyres are the cheapest form of simple fendering. To prevent the suspending chain from chaffing against a vessel's side, a 20-mm diameter bar hanger should be formed and inserted through an incision at the crown of the suspended car tyre (Figure 80). The tyre fender thus presents a clean soft rubbing surface even when compressed against the boat's side.

The fender should be suspended from an anchor bolt cast into the concrete capping block.

Figure 81
Mooring line and sinker

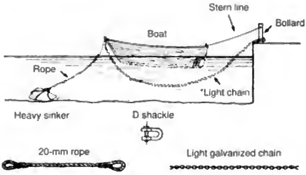


Figure 81 shows a good way of arranging moorings in congested spaces without using buoys or the vessel's anchor.

The mooring consists of a length of light galvanized chain slightly longer than the vessel to be moored. This chain is tied to the bollard and joined to an adequate length of 12 – 20-mm diameter rope via a "D" shackle. The rope, in turn, is attached to a heavy sinker that acts as a permanent anchor on the sea-bottom. On arrival, the fisherman picks up the chain end from the bollard and follows it to the "D" shackle which is then secured to the boat's stern. The bow is then secured directly to the bollard. When the mooring is cast away, the chain sinks to the bottom without fouling the propellers.

Figure 82
Refuelling point

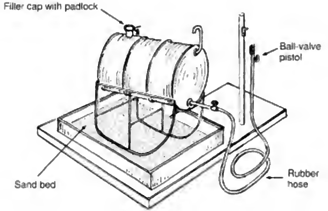
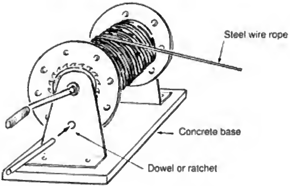


Figure 83
Slipway winch



To avoid pollution, a centrally located refuelling point should be set up (Figure 82). A concrete base, 200 mm thick, should be cast and a containing wall built around the central area. The function of this wall is to collect spilt fuel if the tank leaks. The main valve should be a bronze gate-valve with a padlock. The pistol should be a ball-valve type with no rubber seals (common water taps are not suitable). The end of the hose should be stored higher than the maximum level of the fuel in the tank to prevent accidental leakages. Buckets with sand should be stored nearby to soak up any spilt fuel.

The best way to improve the efficiency of the slipway is to install a simple hand-operated winch, like the one shown in Figure 83. The winch should be anchored to a sturdy concrete base and should have a tooth ratchet installed to prevent accidental slippage. A steel dowel should be used to lock the drum in position.

Although winches can be constructed locally, steel ones are readily available from various sources and it may be worthwhile buying one for use by the whole village.

Figure 84
Drinking-water supply

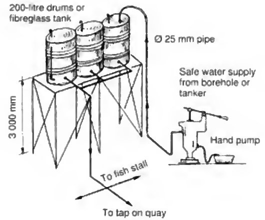
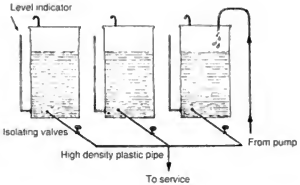


Figure 85
Connecting water tanks



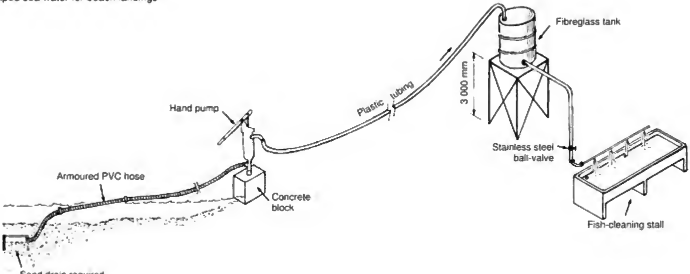
Running fresh water and personal hygiene facilities should be available at all fishing shelters. Figure 84 shows a simple arrangement for providing running water. Drums of 200-litre capacity should be elevated on scaffolding at least 3 m above the ground and water should be pumped by hand-operated pump. Fresh water should be drawn from a reliable source such as a borehole or water-supply truck. Fibreglass or plastic drums may also be used as water storage tanks.

The 200-litre drums may be made out of either galvanized steel or plastic (fibreglass), but all the piping should preferably be made of plastic or rigid PVC. The number of drums (or tanks) needed depends on the size and number of facilities to be provided. Figure 85 shows how several tanks can be interconnected to provide a greater supply of fresh water. Each separate tank has a vent and a stop-cock so that it can be isolated from the others for cleaning without interrupting the supply of water.

Figure 86 shows the arrangement for supplying an isolated beach landing with running sea water, which is suitable for washing fish and for basic personal hygiene.

The most important thing to bear in mind is that sea water corrodes steel very quickly unless the steel is treated with spe-

Figure 86
Piped sea water for beach landings

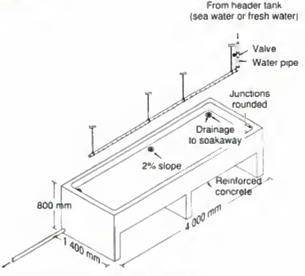


cial coatings. These coatings are very expensive and so the best way to eliminate problems with corrosion is to replace steel fittings with plastic ones wherever possible. Stainless steel fittings are very expensive and should be limited to critical items such as the ball-valve tap.

Both suction and pressure pipes should, therefore, be made of PVC. The header tank should be fibreglass and the hand-pump galvanized to render it suitable for use in sea water.

In areas where the coastline is sandy, the suction hose can either be attached to a jetty pile or breakwater or else be sunk into the sand and attached to a sand drain. The sand drain consists of a pierced drum packed with fine to coarse aggregate. Great care should be taken when constructing it because sand sucked into the pump will eventually damage the pump's foot valve. A simple sand trap is advisable.

Figure 87
Fish stall



100-mm diameter PVC drain pipe to soakaway (sea water) or septic tank (fresh water)

Figure 87 shows a simple fish stall constructed from concrete. A perforated plastic pipe runs over the top of the stall and, via a suitable plastic or stainless steel valve, provides running sea water direct from the sea or drinking-water from the header tank. To avoid polluting the shelter area, the water that runs off the stall, should be piped away into a soakaway if sea water is used. Better still, when drinking-water is used, waste water can be piped into a septic tank (Figure 90).

Figure 88
Soakaway

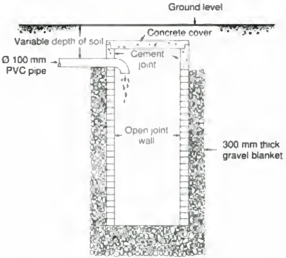
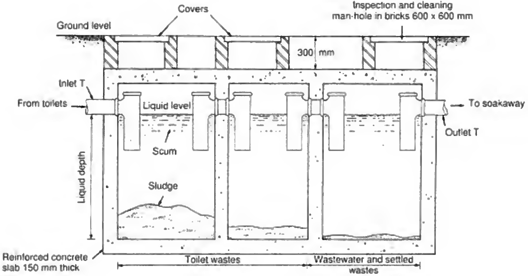


Figure 88 shows a typical soakaway. This is the simplest way to drain biologically polluted effluent into the ground. However, if the soakaway is too close to a groundwater drinking supply, such as a shallow borehole or a well, there is a great risk of polluting the groundwater supply.

As a general rule, in the sandy terrain typical of many coastal areas, the soakaway should be located in the shelter area away from the village wells. Soakaways cannot be used in areas where there is clay in the soil.

Figure 89
The septic tank



Ideally, effluent from both the fish-handling area and the sanitary facilities should be pretreated in a septic tank before being drained into a soakaway. This is not possible, however, when sea water is being piped.

Septic tanks are rectangular chambers with two or three separate compartments (Figure 89). They are usually buried below ground level and receive polluted water from the fish-handling areas and sanitary facilities (toilets).

After coarse screening through a basket sump, the effluent is retained inside the compartments for a period of one to three days. During this period, the solids in suspension settle to the bottom of the tank where they are attacked and digested by bacteria.

As a result, the volume of sludge is greatly reduced and the effluent clarified to some extent.

A septic tank is built if the fishing shelter is big enough to warrant its construction or when the shelter is close to the village fresh-water wells and effluent has to be pretreated before being drained into the soakaway. In any case, when a septic tank is used, the whole water drainage system should be run on *fresh water* and not sea water. Unlike sea water, fresh water will keep the septic tank working at maximum efficiency and will ensure that the effluent leaving it is as unpolluting as possible. Technical help should be sought regarding the dimensions and specifications of the septic tank.

Figure 90a shows a typical beach landing arrangement. The soakaway is close to the fish stall and uses sea water. This layout should only be used if the village is at least 100 m away.

Figure 90b shows a layout where the fish stall is very close to the village's fresh-water well. In this case the soakaway must be placed as far away from the well as possible.

Figure 90c, on the other hand, shows the layout for a combined fishing shelter and village water drainage system. This requires the installation of a septic tank. The fish stall effluent passes through a basket screen and on to the septic tank via a trap. The effluent from the toilets is connected to the septic tank via another trap. The effluent from handbasins, however, is taken to a separate soakaway to prevent detergents from entering the septic tank. This layout should be run on fresh water only. Ideally, the pipes should be in PVC and the slope should be between 2 and 4 percent.

To start the biological process in the septic tank, a piece of rotten meat should be inserted in the first chamber. Special pellets are also available from hardware stores.

Figure 90
Different water drainage systems

Figure 90a
Typical beach landing

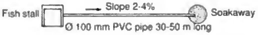


Figure 90b
Fishing village

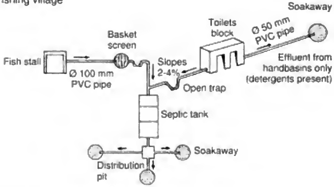


Figure 90c
Combined fishing shelter and village

Figure 91 shows a typical general-purpose shed made of timber. The basic structure of the shed consists of 150-mm diameter timber piles driven into the ground and connected at various levels by timber cross members. Timber trusses support galvanized steel or asbestos sheeting or local thatched roofing. If the timber piles cannot be driven into the ground, concrete foundation blocks should be cast around the bases.

All the timber used in the shed should be treated to protect the structure from possible attack by insects (see Chapter 8). All the fasteners should be made from galvanized steel.

The timber shed can be used for a variety of purposes. It can be used for storage, for boatbuilding, as a fish market or as a fishermen's cooperative, for example.

Should the shed be intended as a fish market (Figure 92), the following additional specifications are recommended:

- The floor of the shed should slope slightly outwards at a slope of about 1:80.
- The floor should consist of a 200-mm-thick concrete slab with a smooth finish to prevent blood from soaking into it. Special surfacing epoxy compounds are available for fish halls.
- The bases of the timber column piles should be protected with concrete to prevent wet-rot from destroying them.
- The floor should drain outwards into a peripheral drain that links up to a soakaway if sea water is used to wash fish, or to the septic tank if fresh water is used.

With the above recommendations, the fish hall can be cleaned easily by a water hose without causing damage to the timber piles.

Cold storage and ice. In warm climates, freshly caught fish spoils very easily. This reduces the value of the catch.

The only ways of preserving fish are by smoking or by some form of cold treatment.

Smoking is only suitable for certain types of fish. In addition, smoking requires large amounts of timber which is a fast-disappearing commodity.

In many cases, cooling may prove to be a more satisfactory method of preservation. On board small fishing vessels cooling can be achieved by putting the fish on crushed ice that is stored in specially made ice-boxes. The ice (in block or flake form) is usually produced at the fishing harbour by an ice-making machine.

Planning the installation of an ice-plant or chill room is a complex exercise and should be left to specialists. Moreover, installing and running an ice-plant is expensive and is only really worth doing when fishermen have access to good markets where they can sell their catch for a high price.

Instead, it may be more cost-effective to buy ready-made crushed ice from commercial suppliers and store it at the harbour in ice-boxes for sale to fishermen, processors and households.

NAVIGATION AIDS

On almost all coasts, landmarks and off-lying hazards, are illuminated at night. These lights can be divided into three categories:

- Landfall lights, including lighthouses, which are invariably very powerful and are usually clearly visible from a great distance.
- Position lights which are also powerful, although their primary function is to indicate the position of a harbour mouth or headland.
- Lighted aids to navigation, including lightbuoys that mark offshore shoals or rocks or navigable channels.

Figure 91
Timber shed

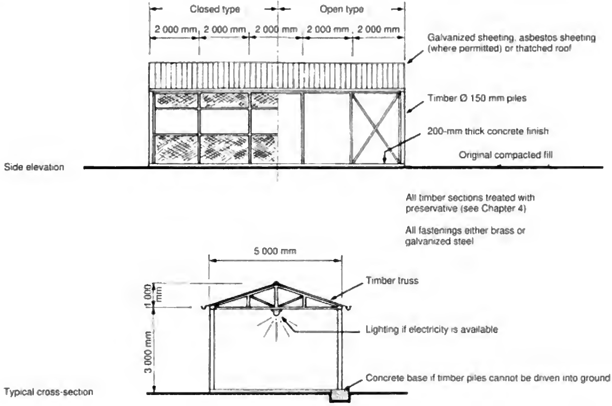
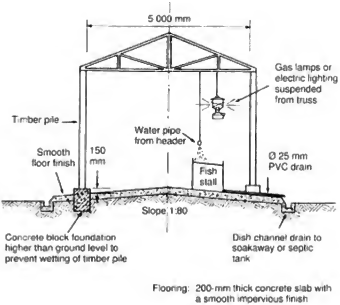


Figure 92
Covered market



All lights, buoys and signs should conform with the specifications contained in the laws of harbours and pilotage of the country concerned.

Lights are distinguishable from each other by their character, colour and period.

Character. A light can be fixed, flashing or occulting. (An occulting light is a fixed or steady light that is eclipsed or blanked-out at regular intervals.) Lightbuoys nearly always carry flashing or occulting lights to distinguish them from the lights of moored vessels.

Colour. Lights should normally be white unless they are for a specific purpose. Position lights, for example, are usually red (port or left side) and green (starboard or right side).

Period. The period of a light is the interval between the beginning of one phase and the beginning of the next one. In a simple flashing light the period is the length of time between one flash and the next; in a group flashing system it is the interval between the beginning of one complete phase of flashes and the beginning of the next.

Before installing any lights, the appropriate government office (navy, coastguard or ministry of works) should be informed so that current sea charts of the area can be revised.

Figure 93 shows a typical marine lantern in high density polyethelene (HDPE) or "heavy plastic". Common plastic should be avoided because it decomposes when exposed to the ultraviolet radiation in rays of sunlight. Most lanterns come with four stainless steel bolts for fixing and a light-cell that automatically switches on the lantern at dusk and off at dawn.

Figure 93
Small marine lantern

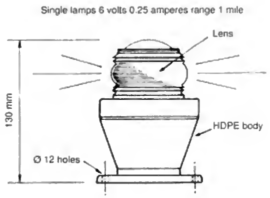
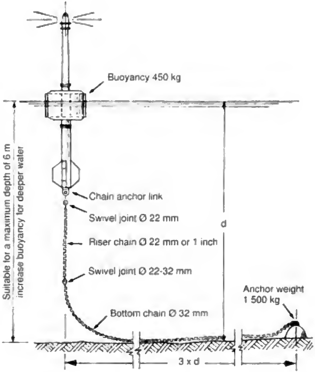


Figure 94
Offshore mooring of marker buoy



More sophisticated lanterns come with an automatic lamp changer which can replace up to six burnt lamps automatically. The visibility of the light from a lantern depends on the power of the lamp and its height above sea level.

At sea or in navigation channels, lanterns are usually mounted on a floating buoy (Figure 95) and anchored (Figure 94).

In tidal areas, where rocks may be exposed at low tide, a fixed marker may be installed as shown in Figure 96.

Figure 95
Floating marker

Figure 96
Fixed marker

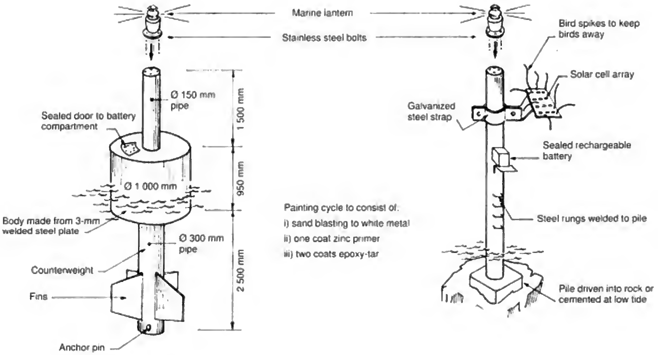
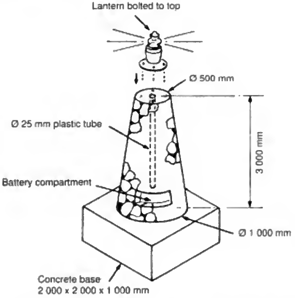


Figure 97
Stone light-tower



Figures 97 and 98 show two ways of building simple light-towers for harbour entrances. A stone tower can be made from locally available rock cemented together. A 25-mm diameter PVC pipe embedded down the middle of the stone light-tower leads to a battery storage compartment. The compartment should face away from the sea and a suitable door in galvanized plate or aluminium should be installed to protect the 12-volt car battery needed to run the light.

Figure 98
Temporary light-tower

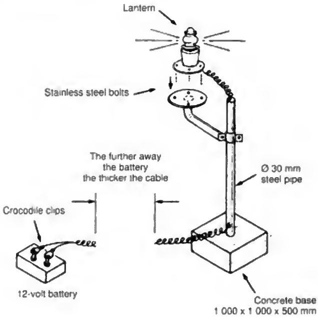


Figure 98 shows a temporary arrangement for a light-tower where the battery is stored a long way from the tower. Great care should be taken in selecting the power cables. If too thin a cable is used, the drop in voltage will be great and the battery will need frequent recharging. The greater the distance between the battery and the light-tower, the thicker the cable has to be.

7. MAINTAINING THE SHELTER

A fishing shelter generally requires regular maintenance to keep it functioning properly.

Shelter maintenance falls under two broad headings:

- Environmental control of naturally occurring phenomena. This type of maintenance includes dredging (sand may silt up the entrance to the shelter periodically) and controlling floating weeds and flotsam.
- Antipollution control of fishing activities. This covers the collection and proper disposal of liquid and solid wastes generated by fishing activities.

DREDGING

If a shelter lies on a sandy coast it may be prone to silting up periodically. In most cases this calls for dredging. Dredging involves the quick removal of accumulated sand by mechanical means and it is a very costly operation.

Before any dredging operations are undertaken, a fairly precise estimate of the volume of dredged material is usually required. This is best achieved by drawing up a grid map of the soundings in and around the shelter area (see Chapter 2) and updating it as required (every six months or yearly). The amount of deposited material can then be calculated and the best type of dredging equipment to use determined.

Loose sand. For very small quantities of sand (1 000 m^3 or less) in the inshore zone, consideration should be given to using either a submersible pump suitable for suspended solids or a hydraulic excavator. Either or both of these items may be available from a local contractor.

A hydraulic excavator should be operated from a mound of core material (see Chapter 3) that has been specially dumped for the purpose. It should work backwards towards land, scooping up both the sand to be dredged and the core.

A suitable submersible pump usually runs on compressed air. The pump can be installed on a fishing boat if the area to be dredged is faraway from the quay.

The size and operating pressure of the compressor determine the maximum working depth of the pump.

For large quantities of sand (1 000 – 10 000 m^3) distributed over a large surface area, a pontoon-mounted excavator should be considered. The operating depth will be governed by the length of the excavator's forearm.

Larger quantities of sand should be tackled by professional dredging contractors using suction dredgers.

When dredging, care should be given to where the dredged sand is to be dumped. It should not be dumped where currents can transport it back to where it was dredged from.

Cemented sand, coral and clay. When the materials to be dredged include lightly cemented sand (weak sandstone), coral and coralline deposits and clays a cutter suction dredger, like the one shown in Figure 68, is usually required to break up the material before it is pumped away for disposal.

For very small quantities, a hydraulic excavator equipped with a very narrow-toothed bucket may suffice.

Hard rock and boulders. In general, a rocky sea-bed cannot be dredged economically. However, rocky outcrops or the occasional boulder can be tackled by explosives and then dredged as normal.

Seaweed. Seaweed may be indigenous to the area where the shelter is located or it may be brought in as flotsam by wind or currents. Non-indigenous seaweed is usually dead.

When seaweed is indigenous the shelter should be dredged to rid the area of roots. This operation may have to be repeated frequently to prevent fresh weed from growing again.

Before uprooting indigenous weed the advice of the fisheries department should be sought. Some seaweeds have important biological functions, such as providing food or nursery grounds for local species of fish, and removing them may damage the environment.

Dead seaweed can either be caught in nets strung across the mouth of a harbour during certain times of year or else it can be collected by hand off the beach after a storm.

Dredging by any other means is very time-consuming and uneconomical because seaweed tends to foul most moving mechanical parts.

Flotsam and bulky waste. In addition to dead seaweed, flotsam can also consist of dead timber or cane brought down a river by a flood. A harbour may also contain manmade rubbish, such as old tyres, pieces of old rope, oil cans and batteries, that has been dumped overboard.

Cleaning a shelter of natural flotsam can be very laborious. Consideration should be given to preventing flotsam from entering the harbour in the first place by stringing a fishing net across the shelter entrance when the wind blows from directions known to bring in floating debris.

Manmade rubbish can only be picked up by a diver or dredged by a crane-operated clam-shell bucket. Both solutions are expensive and antidumping laws should be strictly enforced by the harbour-master to cut down on the amount of manmade rubbish.

POLLUTION ABATEMENT

The pollution in and around most fishing shelters falls into three main groups:

- Visible pollution of the harbour water by spilt fuel or discharged raw sewage. This visibly affects the quality of the water.
- Invisible pollution of the water by hazardous wastes, such as heavy metals (cadmium, mercury, lead, nickel and so on) and paint solvents. This does not affect the appearance of the water but causes invisible pollution.
- Degradation of the natural harbour environment by discarded litter, above and below water level. Though not necessarily toxic, litter dumped into the harbour basin interferes with routine dredging operations, making maintenance very expensive.

The most common pollutants associated with fishing are:

- Spilt diesel fuel from faulty hose pistols, leaking drums and generally careless handling during refuelling operations.
- Discarded used engine oil and bilge water dumped overboard.
- Raw sewage dumped into the harbour from the onboard toilets.
- Offal from fish being gutted and cleaned onboard boats inside the harbour.
- Discarded starter batteries, rechargeable nickel-cadmium cells from radios, torches and walkie-talkies and button cells from watches, calculators, clocks, etc.
- Unwanted tyre fenders, lengths of wire rope, chain and nets dumped into the water.
- Discarded engine blocks and rusting hulls and trailers.
- Discarded containers, such as polystyrene fish boxes, oil and grease cans and paint containers.

All of these pollutants arise from human activities that should be controlled by:

• Quayside regulations and enforcement.
• Waste management and recycling.

Quayside regulations

Quayside regulations are laws designed to protect the environment from abuse by unscrupulous harbour users. In particular, such regulations should prohibit:

• The dumping of crank-case oil and bilge water overboard.
• The flushing of onboard toilets inside the shelter.
• The cleaning of fish onboard moored vessels.
• The discarding of any type of battery.
• The littering of the port area with any kind of waste.
• The use of toxic antifouling paints.

Annex 3 provides a complete series of cartoon drawings entitled "Cleaner harbours". These outline both the sources of pollution and the remedial measures recommended to mitigate them.

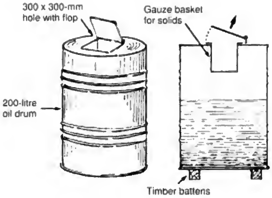
Waste management

Each of the regulations mentioned generates a concentration of waste product which, if not collected and recycled properly, becomes a hazard to the well-being of the fishing community.

To manage this waste properly, a good collection system and a method of recycling or safe disposal are necessary. Both are important and the one cannot be implemented without the other. It is pointless collecting used oil in a big container if the person collecting the oil does not know what to do with it. For waste management to function properly, it must be integrated into the existing commercial or artisanal activities.

The proper ways to collect and recycle various kinds of waste are described in the following pages.

Figure 99
Oil collection



Used engine oil

Collection. The waste oil should be collected in modified 200-litre oil drums (Figure 99) strategically placed inside the fishing shelter. The drums must not remain in contact with the ground because, if they get wet or damp, they may corrode and leak oil.

Recycling. Specialist oil processing companies take back used oil for reprocessing if you can guarantee them a regular supply. Some government agencies actually run a collection system on a national scale for a small fee.

Figure 100
Bilge water separator

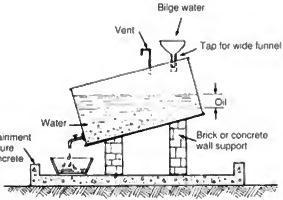
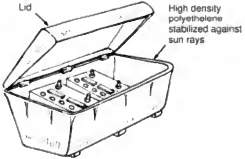


Figure 101
Battery store



Bilge water

Collection. Bilge water consists of sea water mixed with oil that has leaked out of the engine oil-seals. Bilge water should be pumped out from the boats and put into a receiving tank similar to that shown in Figure 100.

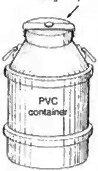
Recycling. Bilge water is easily separated into oil and sea water if it is allowed to settle naturally. Water, being heavier than oil, will settle to the bottom. Using the small tap, it can then be gently drained off into a container and evaporated. The oil/diesel residue can then either be used for heating purposes or poured into the used-oil storage tank.

12-volt starter batteries

Collection. Spent 12-volt batteries contain plates of lead immersed in acid inside a plastic case. Sunlight may decompose the plastic casing, so it is important not to abandon the batteries out in the open. Lead is very toxic and if not handled properly may enter the food chain. Used batteries can be stored in a large bin, as shown in Figure 101, until collected.

Recycling. Most suppliers take spent batteries back for industrial reprocessing. If done properly, lead plates can be recycled at village level to make sinkers for nets. The acid must be disposed of separately in plastic tanks.

Figure 102
Toxic waste container



Toxic solid waste

Collection. Toxic solid waste comprises all those manufactured items that cannot be dissembled. Oil filters, spark plugs, torch and radio batteries, button cells from watches, containers of paint stripper and hydraulic oil are all forms of toxic solid waste. Plastic drums (Figure 102) should be strategically placed around the shelter. Old oil drums which rust and permit toxic chemicals to leach away into the ground are not suitable for these materials.

Recycling. Very little recycling can be done with these items and generally speaking they should be buried in special landfills away from drinking-water wells.

Non-toxic solid waste

Collection. Non-toxic solid waste comprises all other bulky rubbish, such as old tyres, old pieces of rope and netting, broken fish boxes and so on. Figure 103 shows a typical collection point made of locally available stone and concrete (the size of the waste centre depends on local requirements).

Recycling. Metal items should be collected and sold to scrap dealers. Tyres can be turned into fenders, timber fish boxes can be sold as fuelwood. Styrofoam boxes should be avoided because they break up easily and cannot be recycled safely (they give off dangerous fumes when burnt).

Offal

Collection. Fish should be cleaned and gutted on the journey back to the harbour and the offal should be dumped out at sea where it provides food for other fish. Offal should never be dumped inside the harbour basin or discarded in corners within the harbour area or village because, besides giving off offensive smells, it also poses a health hazard by attracting pests. Plastic 100-litre drums with airtight lids (Figure 102) should be bought and used to collect offal from fish markets or moored boats.

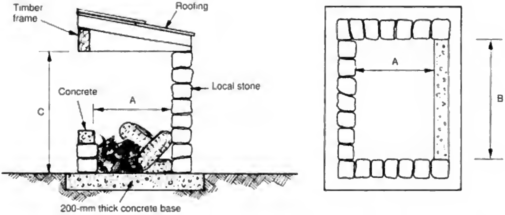
Disposal. When mixed with some types of grain, offal can be used as animal feed or fish silages. Very small quantities can safely be buried.

Sewage

In or around the fishing harbour or landing, the sources of raw sewage may include the village outfall together with the boats' onboard facilities that discharge directly into the water. As described in Chapter 6, the harbour should be provided with toilets and the whole area should be connected to a septic tank and soakaways (Figure 90).

Dumping raw sewage near the fish landing exacerbates health problems, creating a potential flashpoint for disease.

Figure 103
Waste centre



Special note on plastics
Most common household plastic containers (buckets, containers and basins) are not suitable for outdoor use because the PVC they are made from ages rapidly and cracks when exposed to the sun's rays. If such items contain foul or toxic waste, they should not be left exposed to the sun for lengthy periods.

Environmental tips
The following are some additional environment-friendly tips:

- Try not to use polystyrene fish boxes unless absolutely necessary. Rigid plastic ones are available and last longer. If these are too expensive, wooden ones should be used.
- If the fishing village is a long way from a main town or city, consumables should be bought in bulk at village level. For example, instead of buying 50 1-litre cans of oil, a 50-litre drum of oil should be bought by the village and sold by the litre to individual users. A 50-litre drum may be returnable but the 50 1-litre cans have to be disposed of locally because nobody will take them back.
- Moving mechanical parts (such as hinges, winches and ratchets) should be greased and not oiled. Grease tends to stick to the moving part so requires fewer applications. Oil, on the other hand, runs off the part very quickly and needs constant replenishment.

8. CORROSION AND HOW TO AVOID IT

Steel's relatively high strength gives it many advantages as a construction material and steel products can be used in a wide variety of applications.

The most common problem with using steel in a marine environment, however, is that it corrodes easily. Hence, when steel is used, some knowledge of corrosion and of methods for protecting against it is necessary.

CORROSION PROCESS

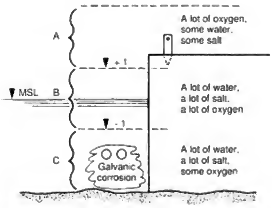
Steel corrodes (that is, rust forms) when it is exposed to oxygen or air. When other atmospheric agents, such as water (rain or moist air) and salt (sea spray), are also present steel corrodes at a much faster rate.

Furthermore, when immersed in sea water, steel is also subjected to galvanic corrosion similar to that which occurs between steel and brass fittings on a boat.

In Figure 104:

- Zone A is exposed to moist air and salt-laden spray, so is a corrosive zone for steel products.
- Zone B is constantly wet with salt-water which also contains a lot of dissolved oxygen. This is the most threatening zone for steel.
- Zone C is also very dangerous for steel because galvanic corrosion is taking place.

Figure 104
Corrosion zones in a marine environment



ANTICORROSION SOLUTIONS

There are five possible ways of protecting steel products against the effects of corrosion:

Use stainless steel instead of normal steel. Stainless steel is normal steel mixed with other metals such as nickel and chrome. However, stainless steel is very expensive and so it is impractical for everyday use except for small fittings such as bolts and nuts.

Coat normal steel with zinc. This is generally referred to as "galvanizing". It is the most common way of protecting small manufactured objects, such as mooring rings, pipe bollards, bolts, clamps, chains, shackles and water pipes. The items to be galvanized are usually dipped in a bath of molten zinc. Once an object has been galvanized, it should not be welded, cut or drilled; these would damage the protective coating.

Coat normal steel with special wear-resistant plastics. The coating process, however, is done at special workshops and is expensive, making this method impractical for everyday use.

Paint normal steel with special paints. This is by far the most common method of protecting large steel structures. Ideally, the surfaces to be painted should be sand-blasted to make them clean and smooth. If this is not possible, they should be thoroughly cleaned with a steel brush. The undercoat should be a zinc-based primer. The second and third coats should be a tar-based epoxy paint.

When painting steel remember:

- Common household paints are not suitable for the marine environment because they age very quickly when exposed to the sun's rays.
- Diesel, kerosene and petrol are not chemically compatible with marine paints and only the proper, recommended paint thinner should be used.
- When handling epoxy-based paints, rubber gloves should always be worn.

Protect normal steel with zinc anodes. This process is called cathodic protection. Zinc anodes are often used in conjunction with painting to further prolong the life of steel structures, such as steel piles, pontoons and metal floats, that are immersed in sea water. Aluminium fittings in contact with wet steel are also subject to galvanic corrosion.

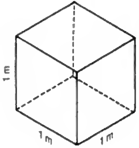
9. WEIGHTS AND MEASURES

The dimensions and weights used in this booklet are all given in metric measurements.

LINEAR MEASUREMENTS
This is how to convert inches, feet and yards into metres:

Multiply	by	to obtain
Inches	0.0254	Metres
Feet	0.3048	Metres
Yards	0.9144	Metres
Metres	39.3701	Inches
Metres	3.2808	Feet
Metres	1.0936	Yards

VOLUMES
The basic metric unit for volume is the cubic metre which is made up of 1 000 litres. The cubic metre is abbreviated in the form m^3.



This is how to convert gallons into litres and cubic metres:

Multiply	by	to obtain
Gallons	4.5460	Litres
Gallons	0.0046	Cubic metres
Litres	0.2200	Gallons
Litres	0.0010	Cubic metres

AREAS
Areas of land are usually measured in local units, which differ from country to country.

In engineering, however, the metric unit of measurement is the square metre (m^2). Large areas are measured in hectares (ha) and vast expanses in square kilometres (km^2).

1 hectare	= 10 000 square metres
1 square kilometre	= 100 hectares

This is how to convert square feet, square yards and acres into square metres:

Multiply	by	to obtain
Square feet	0.0310	Square metres
Square yards	0.8361	Square metres
Acres	4 046.86	Square metres
Square metres	1.1960	Square yards
Hectares	11 960.0	Square yards

WEIGHTS

This is how to convert ounces and pounds into grams, kilograms and tonnes:

Multiply	by	to obtain
Ounces	28.3495	Grams
Ounces	0.0283	Kilograms
Pounds	0.4536	Kilograms
Tonnes	2204.62	Pounds
Kilograms	2.2046	Pounds

Some useful weights

It is useful to know that:

- 1 litre of fresh water weighs 1 kg;
- 1 m3 of fresh water weighs 1 000 kg;
- 1 m3 of sea water weighs 1 020 kg;
- The volume of fresh water 1 000 mm x 1 000 mm x 1 mm (i.e. 0.001 m3) is equivalent to 1 litre and accordingly weighs 1 kg;
- 1 m^3 of cement powder weighs approximately 1 800 kg;
- 1 m^3 of limestone aggregate weighs roughly 2 100 kg. Aggregate made from crushed coral weighs much less depending on the porosity of the coral.

Concrete. 1 m^3 of concrete made with normal aggregates weighs about 2 300 kg. Concrete made with coral aggregate may weigh as little as 1 500 kg per m^3.

However, 1 m^3 of normal concrete immersed in sea water has an effective weight of less than 2 300 kg. This is caused by the uplift of the salt-water and should be borne in mind when casting anchor blocks for vessels. For example, the submerged weight of a concrete anchor block measuring 400 mm x 400 mm x 300 mm can be calculated as follows:

Volume of anchor = 0.4 x 0.4 x 0.3 = 0.048 m^3
Weight in air = 0.048 x 2 300 = 110 kg
Uplift in water = 0.048 x 1 020 = 49 kg
Submerged weight = 110 - 49 = 61 kg

Hence, although the 110-kg anchor block is heavy to handle, it only provides 61 kg of pull when placed in water and may drag along the bottom during rough weather.

Timber. The weight of timber varies according to the species of tree. Here are some examples:

- Opepe weighs about 750 kg/m^3;
- Teak weighs about 640 kg/m^3;
- Ironbark weighs about 1 120 kg/m^3;
- Greenheart weighs about 1 040 kg/m^3;
- Red louro weighs about 640 kg/m^3;
- Blue gum weighs about 830 kg/m^3.

As these weights show, both greenheart and ironbark weigh more than sea water and, so, do not float.

Metals. The weight of a sheet of the following metals, 1 m^2 x 1 mm thick (that is a volume of 0.001 m^3), can be expressed as follows:

Aluminium	weighs	2.56 kg
Zinc	weighs	7.20 kg
Steel	weighs	7.80 kg
Brass	weighs	8.55 kg
Copper	weighs	8.90 kg
Lead	weighs	11.37 kg

CONVENTIONS

Civil engineering, like other branches of engineering, follows preset rules of presentation in order that drawings and plans can be easily read and understood.

Dimensions. On normal drawings, dimensions up to 10 m are usually expressed in millimetres. Over 10 m, dimensions may be expressed directly in metres. Diameters are usually expressed in millimetres; a 100-mm diameter pile is expressed as "ø 100".

Levels. Levels above and below mean sea level are usually expressed in metres up to two decimal places. A quay 1.5 m above sea level is said to be at +1.50 m. Similarly, a sounding that is 2 m deep is expressed as -2.00 m.

When there are tides, which change the depth of the water, all levels should refer to chart datum or low water spring level (LWS) (see Figure 22).

Symbols. The symbols for sand, rock, etc., used in this booklet are internationally recognized symbols (Figure 105).

DRAWING SCALES

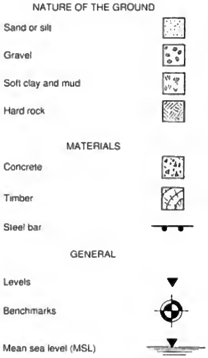
All drawings, apart from sketches, are drawn to a scale (Figure 106).

Drawing scales are necessary to represent actual construction dimensions on paper.

A scale of 1 to 50 or 1:50, means that a length that is 20 mm on the drawing represents 50 time 20 mm, that is 1 m, in real life.

Moving to a smaller scale of 1:100 (the scale 1:50 is twice as big as the scale 1:100), a length of only 10 mm represents 1 m.

Figure 105
International surveying symbols

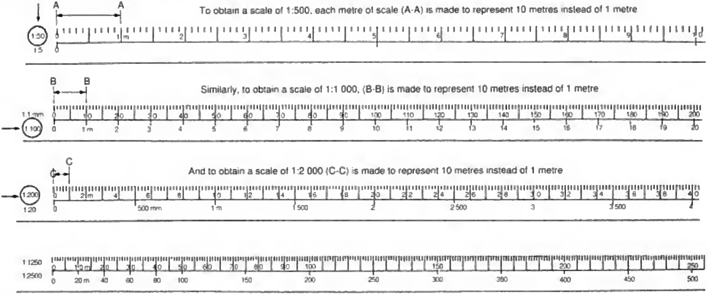


Similarly, on an even smaller scale of 1:200, 5 mm represents 1 m.

What scale and size of paper should be used? The international printing paper A-series is a very common standard and should be used:

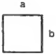
A1-size is 841 mm long and 594 mm wide.
A3-size is 420 mm long and 297 mm wide.

Figure 106
Some commonly used metric scales



AREAS

Square or rectangle

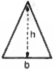


Area = a x b

Circle

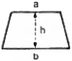
Area = π r x r
where π = 3.14

Triangle



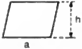
Area = 1/2 (b x h)

Trapezium



Area = h/2(a + b)

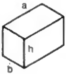
Parallelogram



Area = a x h

VOLUMES

Rectangular solid



Volume = a x b x h

Sphere

Volume = 4/3(π r x r x r)
where π = 3.14

Cylinder

Volume = π r x r x h
where π = 3.14

Cone

Volume = 1/3(π r x r x h)
where π = 3.14

Layout drawings of shelters or harbours should be as big as possible. For example, a stretch of coast 168.2 m long will just fit on to an A1-size paper (841 mm long) if it is drawn at a scale of 1:200 (200 x 841 mm = 168.2 m). If a scale twice as big, 1:100, is used only half the above length, or about 84 metres, would fit on to the same piece of paper.

Construction details, such as cross-sections, require a scale no bigger than 1:50, preferably 1:20.

ANNEX 1. BASIC SAFETY EQUIPMENT

Figure 107 shows a variety of equipment used to ensure the personal safety of workers on construction sites. If finances permit, this equipment should be acquired prior to the start of construction activities.

A plastic helmet or hard hat should be worn at all times, especially where there are suspended loads (cranes) and scaffolding.

Rubber boots should be worn when casting concrete to protect the feet from contact with cement which can cause the skin to crack and bleed.

Rubber gloves should be worn by workers handling cement, fresh concrete and marine epoxy paints.

A face mask with a filter element must be worn by workers handling, opening and emptying cement bags at the concrete mixer.

Dark-glass goggles must be worn when welding and clear glass goggles when cutting.

Figure 107
Some safety equipment

Figure 107a
Hard hat

Figure 107c
Rubber gloves

Figure 107b
Rubber boots

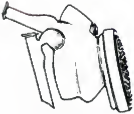


Figure 107d
Face mask

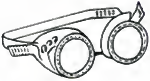
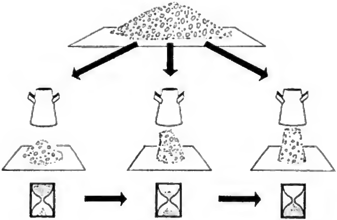


Figure 107e
Welding goggles

ANNEX 2. HANDLING CONCRETE

Figure 108 shows how a good workable concrete mix turns stiff over time. When this happens more water must be added to render the concrete workable again, and this reduces both its strength and durability.

Figure 108
Workability of concrete with time

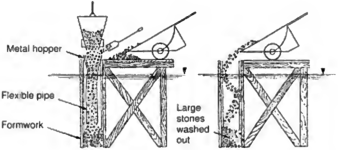


A workable mix will stiffen more rapidly when:
- a porous aggregate is used;
- the aggregate contains too much dust;
- the temperature of the aggregate is too high.

As well as using good materials, as described in Chapter 4, concreting should be carried out early in the morning, before the sun has had time to warm up the aggregate stockpiles.

The formwork should always be prepared the previous day. It should then be oiled just prior to concreting, making sure that no oil gets on to the steel reinforcing bars.

Figure 109
Placing concrete under water



When concrete has to be poured underwater a tremie should be set up as shown in Figure 110a. This prevents the water washing the large aggregate out of the concrete mix (Figure 110b). The tremie is gradually pulled up as the pipe fills with concrete. The cement content for an underwater mix should be double that of the 1:2:4 mix described in Chapter 4. In other words, it should have one part cement for every one part of sand and two parts of aggregate.

Figure 110a
Incorrect use of concrete vibrator

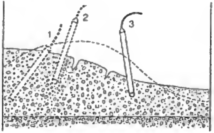
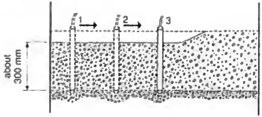


Figure 110b
Correct use of concrete vibrator



All concrete that is not laid underwater should be vibrated using a poker vibrator like the one shown in Figure 74c. The vibration compacts the fresh concrete by eliminating the air pockets trapped in the mix during the mixing. This generally allows the use of a drier mix (i.e. less water is required for compaction), which enhances the strength and durability of the finished concrete. Concrete that is over-vibrated, on the other hand, causes separation or segregation of the aggregate.

To achieve the right standard of compaction the poker should be worked into the concrete at regular intervals in an orderly fashion (Figure 110b). Each successive layer should be no deeper than 300 mm. In Figure 110a, the poker has been operated in a haphazard manner producing a substandard cast.

CURING

As soon as new concrete has been laid, the exposed surface should be covered with jute or reed mats and water sprinkled on it at regular intervals for at least three days. This prevents the concrete from drying out too rapidly. If left exposed to the sun the surface will dry very quickly, shrink and crack. Once shrinkage cracks develop, the surface cannot be repaired and the concrete casting will deteriorate very rapidly.

Freshly cast concrete will only reach maturity after 28 days, but precast elements can usually be handled after seven days.

ANNEX 3. TIPS ON CLEANER HARBOURS

Regulation No. 3 of Annex V of MARPOL 73/78, *Regulations for the prevention of pollution by garbage*, states:

> "the disposal into the sea of all plastics, including but not limited to synthetic ropes, synthetic fishing nets and plastic garbage bags, is prohibited."

Annex V came into force on 31 December 1988 and as such should form the basis of the quayside regulations mentioned in Chapter 7.

With this in mind, a series of cartoon drawings has been drawn up as an aid to antipollution awareness programmes, these are on pages 108-138.

The cartoons were drawn up for use in the Mediterranean sea area and should be adapted to make them compatible with other regions of the world.

Who should use them? The drawings are for use in those countries where the artisanal fisheries industry is expanding rapidly. Extension workers in the field, fisheries training colleges, fisheries enforcement officers and harbour-masters should find them useful. The drawings may also be used as part of an elementary public awareness programme within a larger educational framework. Some of the drawings are also suitable as posters.

How can they be used? To be used effectively, the drawings should first be enlarged to A3-size. Then they should be customized to reflect the local fisheries scene; for example, the fisherman illustrated could be given a local look by altering his facial features, hat and attire; the fishmonger may have to be female to reflect certain traditions; the vessels should reflect local craft as much as possible and so on.

Instances depicted in the drawings in the country of intended use can then be photographed on slides. A trip round the coastal areas will usually present numerous opportunities to photograph the conditions outlined in the drawings.

Finally, the drawings themselves should be transferred to slides and a package prepared consisting of a sequence of the 31 drawings with, say, an equal number of case histories sandwiched in-between.

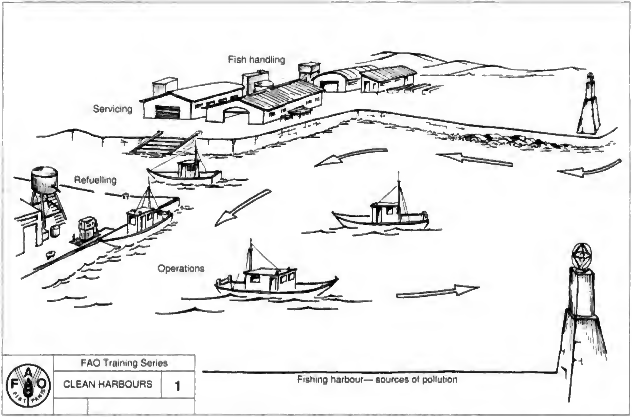
The slide package should then be run on a good slide projector with a qualified person giving a running commentary. This will inevitably mean that the same person has to go round the various local landings, unless more copies and projectors are made available.

An even better alternative is to tape the entire package and commentary on a video cassette and distribute copies around the country. Suppliers to the fisheries industry (net manufacturers, engine suppliers, boat builders, oil companies, etc.) may act as sponsors of the video cassettes by paying to advertize. This would cut costs considerably.

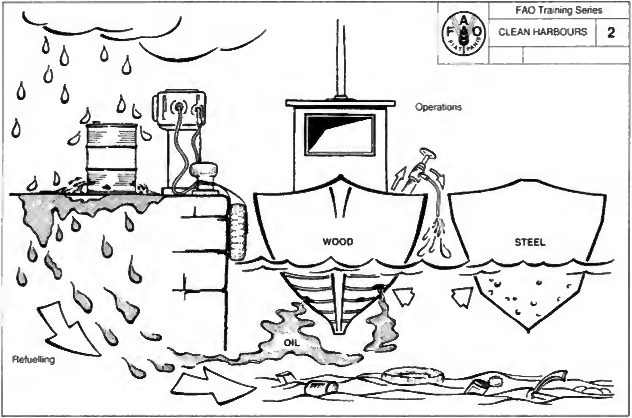
Each of the cartoons on the following pages has a caption describing the message intended to be conveyed to the fishing community. Individual users of the package can then elaborate further on each topic.

It must be stressed that the programme's humorous side is intended as a psychological tool to make offenders aware of their misdeeds without antagonizing them or anybody else.

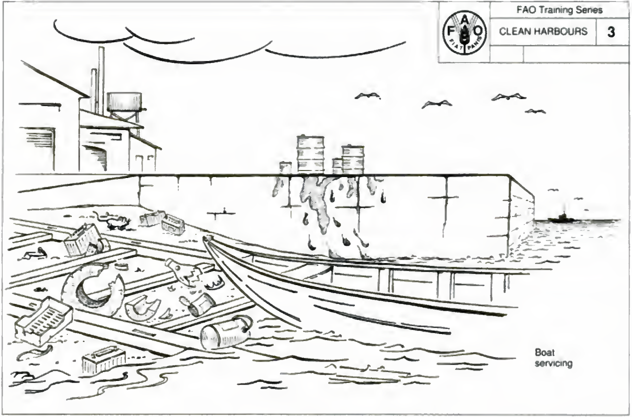
Further suggestions would be welcome.



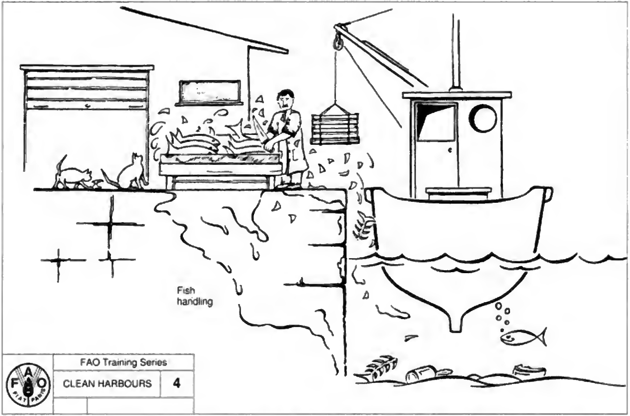
Drawing No. 1 outlines the four major sources of pollution in a typical fisheries harbour: operations ; handling; servicing; and refuelling.



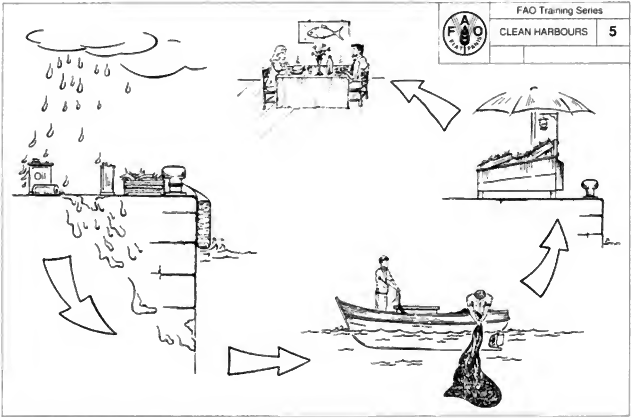
Drawing No. 2 shows how spilt fuel oil attacks the caulking on timber vessels. Metal cans on the sea-bed attack metal hulls and fittings, such as the propeller and the shaft.



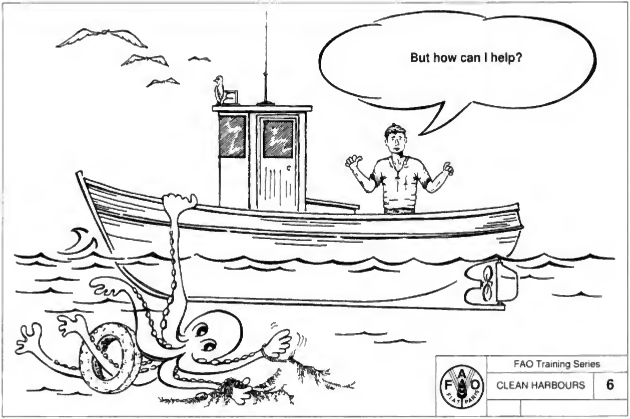
Drawing No. 3 shows the discarded waste that is typical when vessels are serviced carelessly.



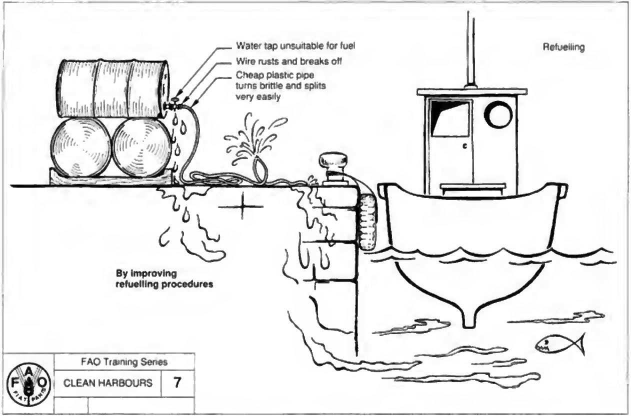
Drawing No. 4 emphasizes the health hazard of gutting fish inside the harbour – pests are invariably drawn to the area.



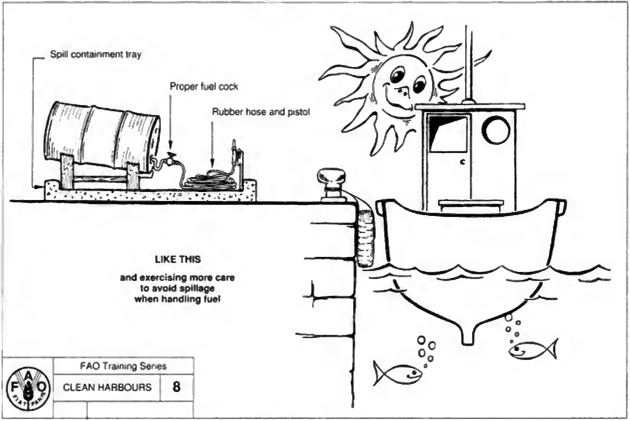
Drawing No. 5 shows how dangerous chemicals find their way into the food-chain.



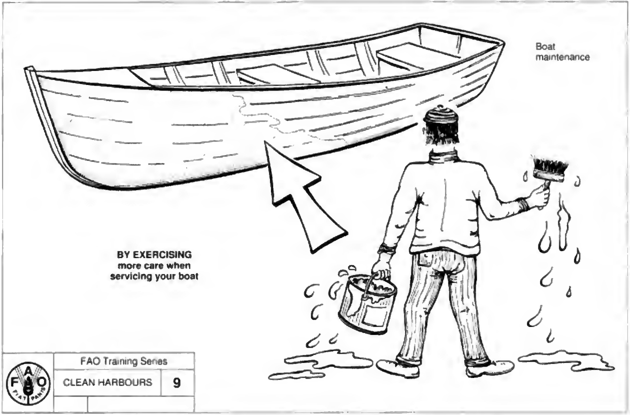
Drawing No. 6 asks the important question without laying blame on any one particular sector of the fisheries industry.



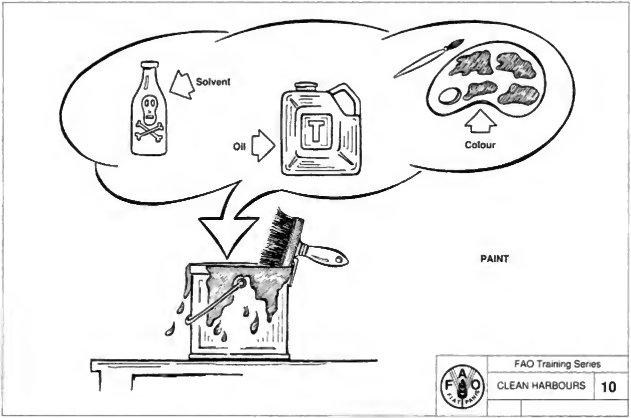
Drawing No. 7 shows the typical mistakes made by people who are not aware of the consequences of spilling fuel. Case history slides should be inserted in-between slides of drawings No. 8 onwards.



Drawing No. 8 shows the correct way to store and dispense fuel at the quayside.

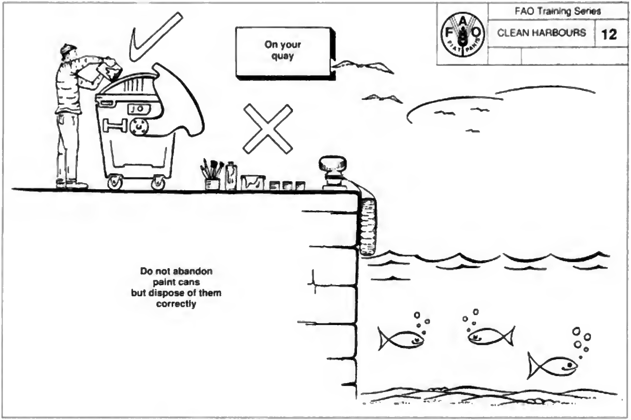


Drawing No. 9 shows a careless boat owner servicing his boat with little attention to the mess around him.

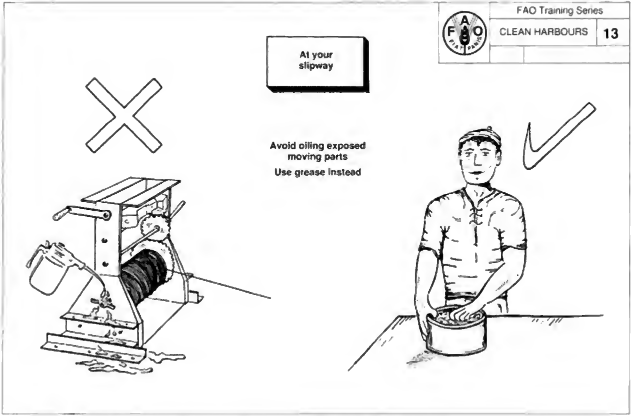


Drawing No. 10 explains in very simple terms the various chemicals that make up paint and their toxicity to humans.

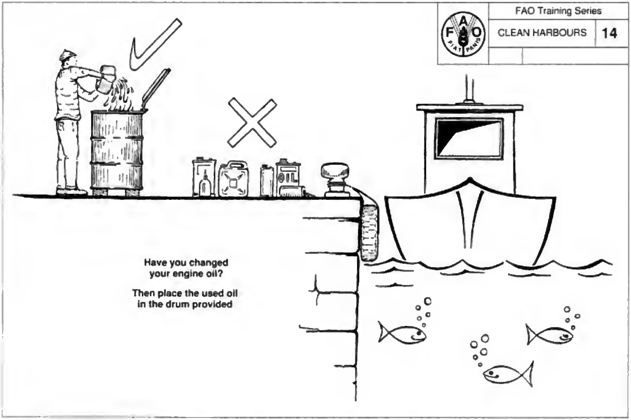
Drawing No. 11 stresses the point that any material abandoned near the water's edge invariably ends up in the water. For example, wind blows some empty cans and children kick the rest in.



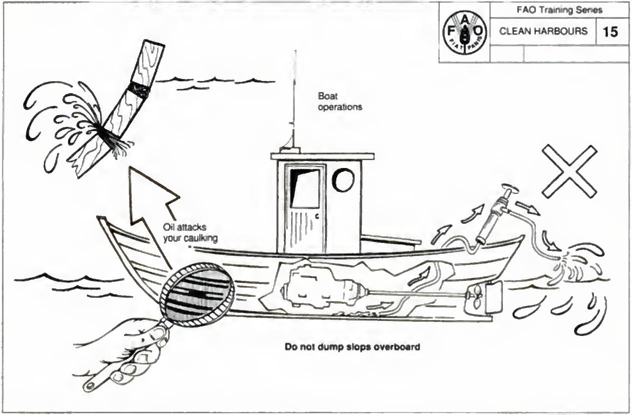
Drawing No. 12 shows the correct method of can disposal. The container shown should look like the one intended for use at the particular landing.



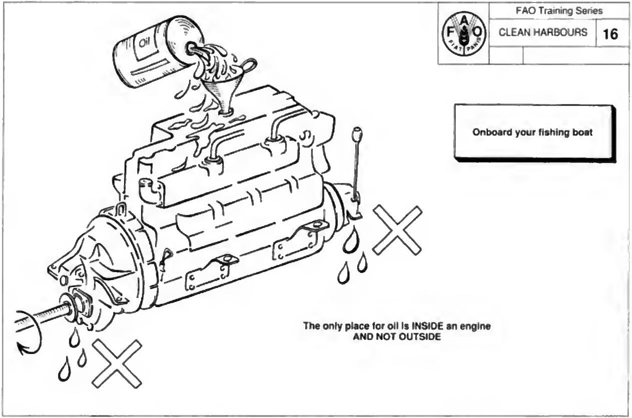
Drawing No. 13 explains the importance of greasing moving parts rather than oiling them.



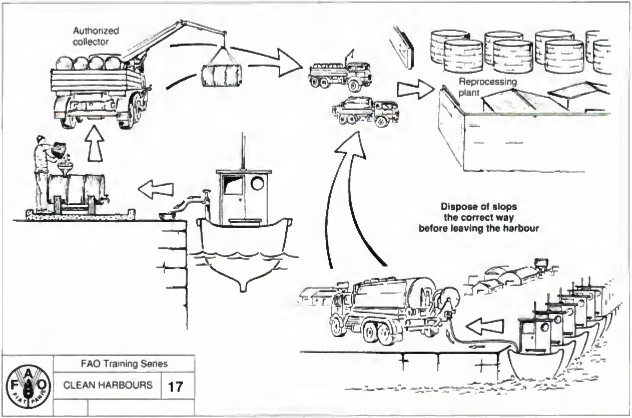
Drawing No. 14 shows the correct method of oil disposal. The container shown should look like the one intended for use.



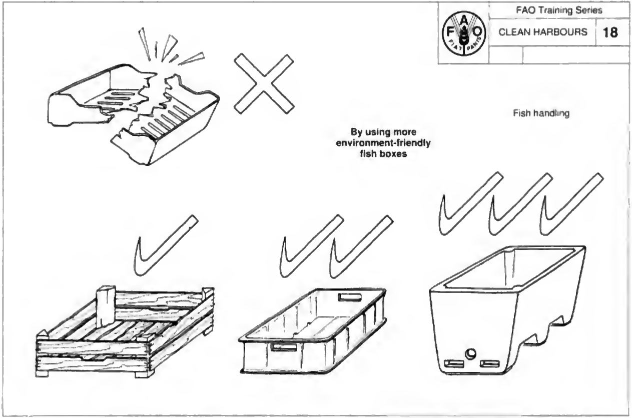
Drawing No. 15 shows the effect that oil has on a vessel's caulking.



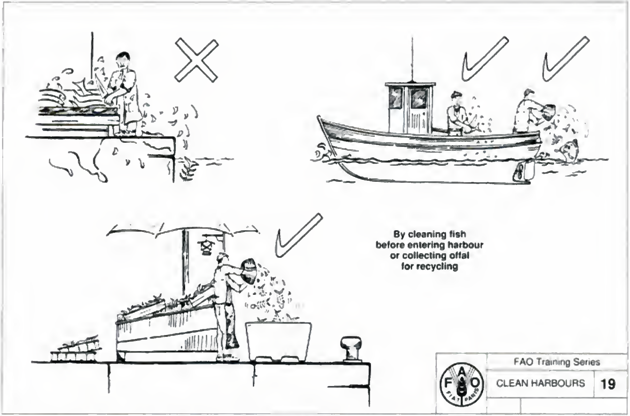
Drawing No. 16 emphasizes the need to maintain engines properly (oil seals) and avoid oil spillage. If outboards are very popular in a specific country, an outboard engine should be added to this drawing.



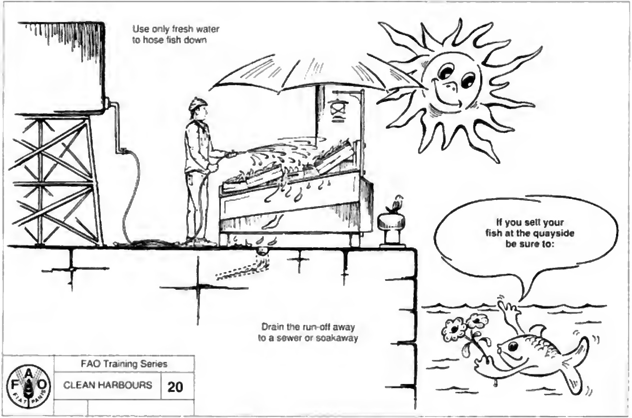
Drawing No. 17 shows collection and treatment of slops at both the artisanal and industrial levels.



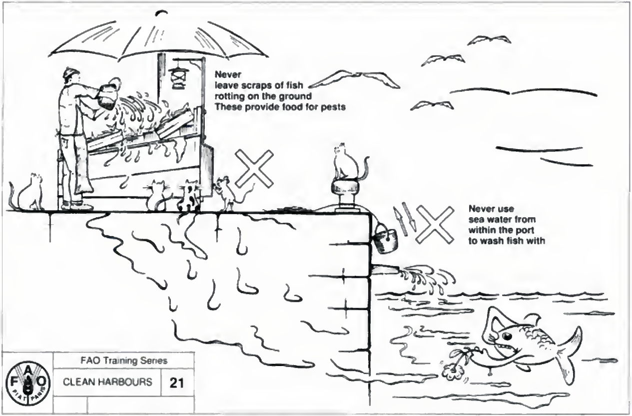
Drawing No. 18 suggests more environment-friendly methods of storing fish. Foam and timber boxes accumulate bacteria and are not suitable for continuous use. However, timber boxes are made locally and can be used as fuel when they break.



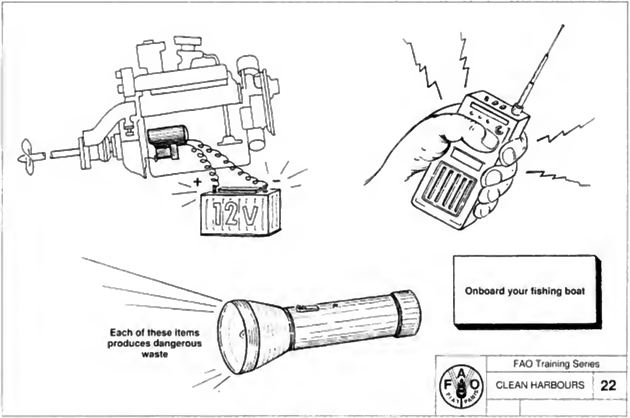
Drawing No. 19 shows how to keep the problems associated with offal to a minimum.



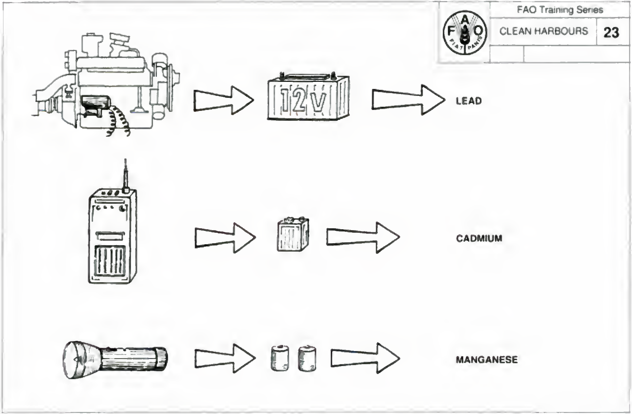
Drawing No. 20 explains the importance of using clean fresh water to rinse fish. Note also that the run-off containing blood is drained into a soakaway and not into the harbour.



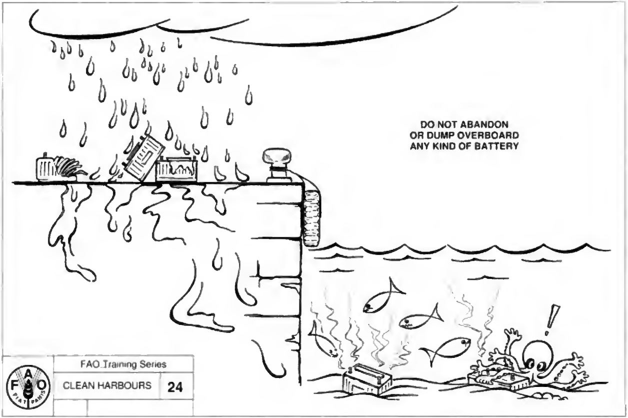
Drawing No. 21 shows bad fish-cleaning techniques. The fishmonger is using dirty water from the harbour, where raw sewage might be present, and dumping scraps of fish which attract pests and disease. Note the absence of soakaway.



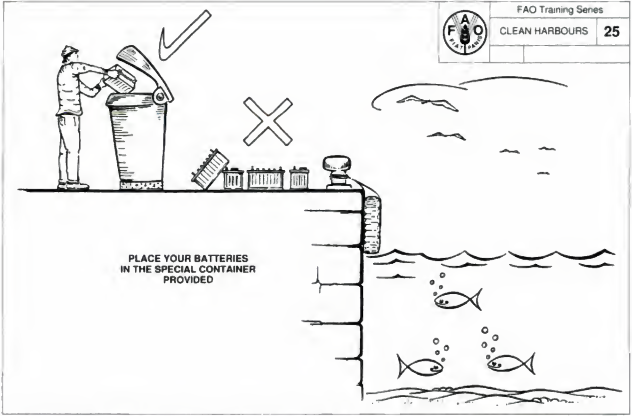
Drawing No. 22 illustrates the sources of highly toxic heavy metal pollution.



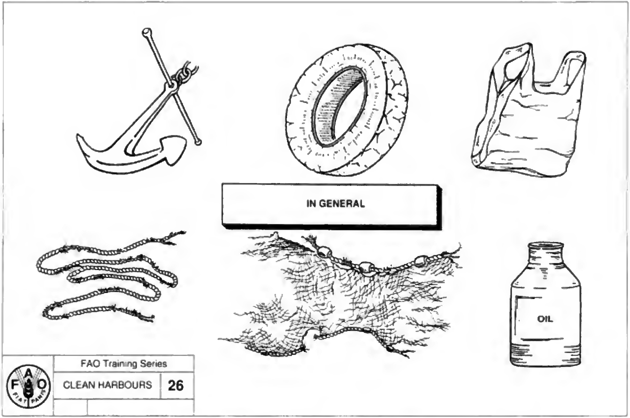
Drawing No. 23 shows which toxins the items shown in Drawing No. 22 contain. Although the manganese powder filling of the torch battery is not considered toxic, it always contains traces of mercury which is highly toxic.



Drawing No. 24 illustrates how batteries break up and release toxic lead into the environment.

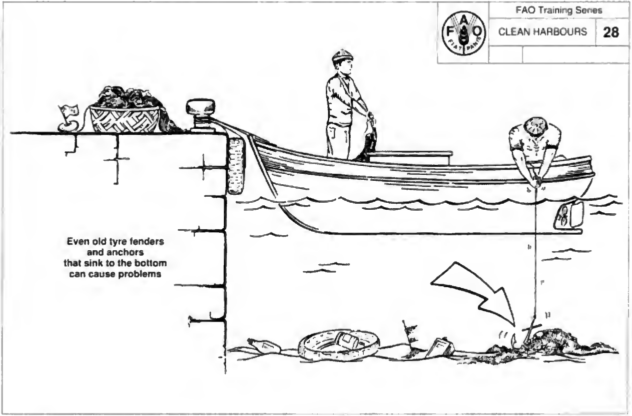


Drawing No. 25 illustrates a recommended collection method. The size and shape of containers illustrated should match local market conditions.

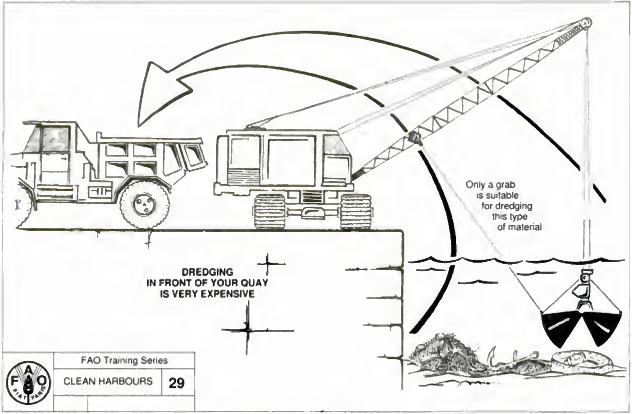


Drawing No. 26 illustrates items which are sometimes "lost" over the side of boats.

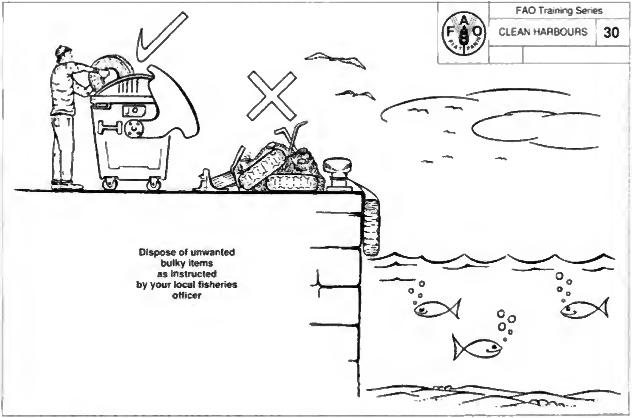
Drawing No. 27 illustrates two cases where such items cause inconvenience to other vessels.



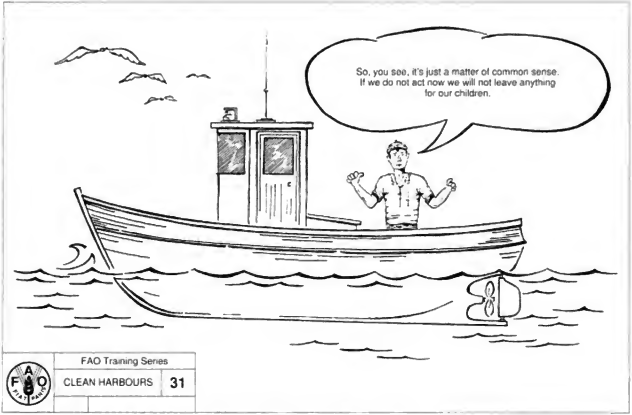
Drawing No. 28 illustrates another such inconvenience.



Drawing No. 29 focuses on the cost of removing this sort of rubbish.



Drawing No. 30 illustrates the correct method of rubbish disposal. The container should resemble the one intended for use.



Drawing No. 31 can be used to illustrate the commentator's summing-up remarks.

REFERENCES

The following is a list of publications on the protection of the marine environment that are published by the International Maritime Organization, Publications Section, 4 Albert Embankment, London SE1 7SR, UK.

These publications provide governments, particularly those of developing countries, with an overview of practical guidelines to combat pollution at sea.

Guidelines on the provision of adequate reception facilities in ports
Part I (oily wastes), Part II (residues and mixtures containing noxious liquid substances), Part III (sewage), and Part IV (garbage)
Catalogue No. 5807702E, 1976;
Catalogue No. 5828609E, 1986;
Catalogue No. 5847812E, 1978.

Manual on oil pollution
Section I (Prevention), Section II (contingency planning), Section III (salvage), Section IV (combatting oil spills).
Catalogue No. 5578301E, 1983;
Catalogue No. 5608802E, 1988;
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This manual is the latest in the training series of the Fishing Technology Service of FAO. It was conceived as a result of the increasing demand in many developing countries for safer, better and cleaner facilities for fishing vessels, particularly for the smaller craft used by small-scale artisanal fishermen and -women. It describes the equipment and methods used in the construction of harbours and landing places and gives advice on how to maintain them so that they can function efficiently.

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